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CONTENTS

	Page
Distillers' By-Products in Swine Rations. II. Lactation and Growing-Fattening Rations. J. L. Krider, B. W. Fairbanks, and W. E. Carroll	107
The Effect of Sex on the Development of the Pig. III. Differences in Growth Rate Between Gilts and Barrows by Lines of Breeding. R. E. Comstock, L. M. Winters, and John N. Cummings	120
A Variable Physiological Factor Necessary for the Survival of Bull Spermatozoa. John F. Lasley and Dennis T. Mayer	129
Studies with Swine on Low-Manganese Rations of Natural Foodstuffs. S. R. Johnson	136
Feed Utilization Tests with Cattle. H. R. Guilbert and P. W. Gregory	143
Rate of Conception in Beef Cows Pasture-Bred During a Controlled Breeding Season. A. O. Rhoad	154
Clean-Wool Yields in Small Samples from Eight Body Regions as Related to Whole-Fleece Yields in Four Breeds of Sheep. Elroy M. Pohle and L. N. Hazel	159
The B Vitamin Requirements of the Horse. P. B. Pearson, M. K. Sheybani, and H. Schmidt	166
Some Factors Affecting the Blood Phosphorus Level of Range Ewes. W. M. Beeson, Clair E. Terrill, and D. W. Bolin	175
The Failure of Ascorbic Acid to Augment Equine Gonadotropin in the Rat. John O. Almquist and Frederick N. Andrews	183
The Development of Body Form in Swine. R. E. Comstock and L. M. Winters	188
A Preliminary Report on the Post-Natal Development of the Fiber Characteristics of the Fleeces of Navajo Sheep. James O. Grandstaff and Cecil T. Blunn	194
Selection for Growth Rate of Pigs and Productivity of Sows. G. E. Dickerson and L. N. Hazel	201
News and Notes	213

Contents of previous issues of the JOURNAL OF ANIMAL SCIENCE are indexed in the Agricultural Index, which is available in most libraries.

DISTILLERS' BY-PRODUCTS IN SWINE RATIONS

II. LACTATION AND GROWING-FATTENING RATIONS[1]

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IN A PREVIOUS paper (Fairbanks, Krider, and Carroll, 1944) it was shown that the addition of either dried corn distillers' solubles or corn distillers' dried grain with solubles improved a basal ration composed of commonly used ingredients for growing-fattening pigs in drylot. Moreover, pigs fed the fortified rations up to weaning and then changed to a basal growing-fattening ration manifested a residual effect. The nutritional improvement and residual effects were attributed to the known or unknown factors of the B_2 complex in the distillery by-products.

Certain rations composed of natural ingredients are nutritionally inadequate for growing-fattening swine in drylot and for sows and gilts during gestation and lactation according to the experimental reports of Aubel, Hughes, and Lienhardt, 1932; Ellis, Craft and Zeller, 1936; Ellis and Madsen, 1941; Eveleth and Biester, 1937; Hogan, 1932; Hogan, Casida and McKenzie, 1928; Hogan and Johnson, 1940, 1941; Hogan, Johnson and Gahley, 1938; Hogan and McRoberts, 1940; and Ross, Phillips and Bohstedt, 1942, 1942a.

The experiment reported herein was designed to confirm in part the previous work. In addition dried corn distillers' solubles were used to fortify a dry-lot lactation ration composed of natural ingredients and alfalfa meal was used as a supplement to a basal drylot growing-fattening ration composed of commonly used feeds. Sun-cured alfalfa meal is known to be a source of vitamins A and D and of certain water-soluble vitamins (Hogan and Johnson, 1941; Ross, Phillips and Bohstedt, 1942, 1942a). Since fortified cod-liver oil was added to the basal ration, the vitamins A and D requirements were met, so any observed differences due to the addition of alfalfa meal may be attributed to its vitamin content other than vitamins A and D.

Objects

1. To compare a basal lactation ration composed of ground yellow corn, tankage, soybean meal, alfalfa meal and minerals with the basal ration sup-

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plemented with six percent of dried corn distillers' solubles in drylot.

2. To compare a basal growing-fattening ration composed of ground yellow corn, wheat flour middlings, soybean meal, tankage, fish meal, fortified cod-liver oil and minerals with the basal ration supplemented with dried corn distillers' solubles at six and twelve percent levels when fed in the drylot.

3. To study the value of adding alfalfa meal to the basal ration for growing-fattening pigs in drylot.

4. To observe the residual effects of fortifying the sow's lactation ration upon the performance of her pigs during the growing-fattening period.

Experimental Procedure

Figure 1 shows the grouping of the sows during lactation and the allotment of their pigs at weaning time.

A. Farrowing to Weaning (All pigs received dam's milk only.)	B. Weaning to Market (All pigs self-fed)
Group I (Sows)	Lot 1 Basal
Basal	Lot 2 Basal+6% dried corn distillers' solubles
(At 56 days of age pigs were allotted to Lots 1, 2, 3, and 7)	Lot 3 Basal+12% dried corn distillers' solubles
	Lot 7 Basal+alfalfa meal
Group II (Sows)	Lot 4 Basal
Basal+6% dried corn distillers' solubles	Lot 5 Basal+6% dried corn distillers' solubles
(At 56 days of age pigs were allotted to Lots 4, 5, and 6)	Lot 6 Basal+12% dried corn distillers' solubles

Figure 1. Diagram showing division of pigs into lots and treatments given in 1942 spring test. (Drylot feeding.)

Twenty sows and their litters were assigned to Groups I and II and equated for age, breed, weight of sow, and size and weight of litter. All sows were fed and managed alike during gestation and accorded the same treatment until the start of the experiment which was, on the average, ten days after farrowing. The basal lactation ration was fed to the sows of Group I while the sows of Group II received the basal ration supplemented with six per cent dried corn distillers' solubles. The pigs did not have access to the rations fed their dams. All pigs were protected from nutritional anemia.

At weaning time the pigs of Group I were assigned to Lots 1, 2, 3, and 7, while those of Group II were assigned to Lots 4, 5, and 6. (See figure 1.) The lots from each group were equated for weight, sex, breeding and condition.

It is significant to note that the only difference in the management of Lots 1, 2, and 3 and Lots 4, 5, and 6 was that the pigs of the latter group suckled dams fed a suppplemented lactation ration.

The individual pigs were weighed every two weeks until near the end of the experiment when weights were taken weekly. Each pig was weighed off the test on the weigh day at which its live weight approximated 225 pounds. As all pigs in Lot 3 reached the final weight of 225 pounds, the experiment was arbitrarily closed on the day the last pig was weighed-off this lot.

Basal Rations and Supplementary Feeds Used

1. *Lactation Rations*

The following rations were fed to the sows during lactation:

Ingredients	Basal (Ration 12)	Fortified Basal (Ratio 12a)
Ground yellow corn	83	80
Tankage	8	8
Soybean meal	4	1
Dried corn distillers' solubles	—	6
Alfalfa meal	4	4
Mineral mixture, { Ground limestone 2; Steamed bone meal 2; Salt 1 }	1	1

The chemical analysis and vitamin assays are given in Table 1. The dried corn distillers' solubles used were previously described by Fairbanks, Krider and Carroll (1944).

2. *Growing-Fattening Rations*

The basal growing-fattening rations fed to Lots 1 and 4 (table 1) and the adjustments made according to weight were as follows:

Ingredients	Weaning to 50 lbs.	50 lbs. to 100 lbs.	100 lbs. to 225 lbs.
Ground yellow corn	48.0	61.1	85.7
Wheat flour middlings	12.0	15.3	—
Soybean meal	20.0	11.8	7.1
Tankage	14.0	8.2	5.0
Fish meal	6.0	3.6	2.2
Mineral mixture, { Ground limestone 2; Steamed bone meal 2; Salt 1 }	2.0	2.0	2.0
Fortified cod-liver oil	0.5	0.5	0.5

The basal rations were supplemented with six per cent dried corn distillers' solubles (Lots 2 and 5, table 1) and with 12 per cent dried corn distillers' solubles (Lots 3 and 6, table 1). The pigs of Lot 7 (table 1) were fed the basal ration supplemented with 12 per cent alfalfa meal from weaning to 50 pounds, with eight per cent from 50 to 100 pounds, and with four per cent from 100 pounds to market weight. The alfalfa meal was of average quality but of unknown origin.

The feed mixtures were equalized for their crude protein content and

TABLE 1. CHEMICAL COMPOSITION AND VITAMIN CONTENT OF RATIONS FED TO THE SOWS DURING LACTATION AND OF RATIONS FED TO THE PIGS FROM 50 TO 100 POUNDS IN WEIGHT, SPRING 1942

Ration number	12	12a	50	51	57	6
Treatment	Basal	Basal & 6% dried corn distillers' solubles	Basal	Basal & 6% dried corn distillers' solubles	Basal & 12% dried corn distillers' solubles	Basal & 8% alfalfa meal
Fed to:	Group I (sows)	Group II (sows)	Lots 1 & 4 (pigs)	Lots 2 & 5 (pigs)	Lots 3 & 6 (pigs)	Lot 7 (pigs)
Crude protein, per cent	14.44	14.50	19.28	19.78	18.90	20.25
Fat, per cent	2.48	1.74	2.44	2.50	2.77	3.76
Fiber, per cent	3.36	3.19	2.72	2.36	2.27	3.94
Ash, per cent	3.96	4.01	6.27	6.04	6.48	6.18
Calcium, per cent	.79	.79	1.35*	1.37*	1.38*	1.33
Phosphorus, per cent	.52	.58	.85*	.89*	.98*	.85
Manganese, p.p.m.	—	—	21.5	24.	25.	25.
Vitamin A, I.U. per lb.	3166.*	3066.*	8774.*	8494.*	8446.*	9488.*
Vitamin D, A.O.A.C. chick units per lb.	—	—	886.*	886.*	886.*	886.*
Riboflavin, mg. per lb.	.86**	1.27**	1.18**	1.82**	2.18**	2.26**
Niacin, mg. per lb.	6.81**	9.50*	8.17**	11.35**	11.80**	26.2**
Pantothenic acid, mg. per lb.	3.04**	3.98*	4.09*	4.41*	4.69*	4.64*

* Estimated from literature or from unpublished Illinois data.

** The samples were assayed for riboflavin according to the method of Snell and Strong (Ind. and Eng. Chem. Anal. Ed. 11: 346, 1939), for niacin according to the method of Snell and Wright (J. Biol. Chem. 139: 675, 1941), and for pantothenic acid according to the method of Pennington, Snell and Williams (J. Biol. Chem. 135: 213, 1940) with slight modifications. Acknowledgment is made to the Animal Nutrition Division for making these assays.

adjusted for weight of pig as follows: for pigs from weaning to 50 pounds, 25 per cent; for pigs from 50 to 100 pounds, 20 per cent; for pigs from 100 pounds to market weight, 15 per cent.

The chemical analysis and vitamin assays of the growing-fattening rations fed to pigs from 50 to 100 pounds are presented in table 1. If it is assumed that growing-fattening pigs of this weight consume from four to five per cent of their body weight as feed per day, than all rations, including the basal, supplied more than the minimum requirements of riboflavin and niacin

(Hughes, 1940, 1943) and of pantothenic acid (Hughes and Ittner, 1942). The limitations of microbiological assay were discussed by Fairbanks, Krider and Carroll (1944).

Results and Discussion

1. *Lactation.* The essential data are presented in table 2. The slight differences in the gains of the sows and pigs were not statistically significant. Liberal feeding of the sows is indicated by their gain in live weight during lactation. The small weaning weights of the pigs of both groups are explained in part by the severe experimental conditions imposed in order to test the effect of the two rations on lactation. The death losses in both groups were

TABLE 2. FORTIFYING THE BASAL RATION OF LACTATING SOWS WITH DRIED CORN DISTILLERS' SOLUBLES. SPRING 1942
(Drylot Feeding)

Rations	Group I Basal (Ration 12)	Group II Basal & 6% dried corn distillers' solubles (Ration 12a)
Number of sows	11	9
Number of pigs started	76	60
Number of pigs died during test	4	1
Avg. initial litter age (days)	10.2	10.2
Avg. gain of sows, lbs.	18	17
Avg. initial weight of pigs, lbs.*	6.3	6.0
Avg. final weight of pigs, lbs.*	20.8	20.0
Avg. gain of pigs, lbs.*	14.5	14.0
Avg. daily gain of pigs, lbs.*	.31	.30

* For the pigs that finished.

low. At weaning time no important measurable differences existed between the two groups of sows and their litters.

2. *Growing-Fattening.* The essential data for the seven lots of pigs following weaning are presented in table 3. The growth curves for the first 24 weeks are graphically represented in Figure 2 and grouped according to the treatment of their dams during lactation, namely Lots 1, 2, 3, and 7 from sows receiving the basal lactation ration and Lots 4, 5, and 6 from sows receiving a supplemented lactation ration. Since only 50 per cent of the pigs survived in Lot 1, the growth curve for this lot is represented by a solid line up to the time that six of the pigs had died and by a broken line from there on. The seventh pig died ten days before the close of the experiment.

TABLE 3. THE RESULTS OF ADDING EITHER SIX OR TWELVE PER CENT OF DRIED CORN DISTILLERS' SOLUBLES OR ALFALFA MEAL TO THE BASAL RATION FOR GROWING-FATTENING PIGS IN DRYLOT FROM WEANING TO MARKET, SPRING 1942. (All Pigs Self-Fed)

Rations fed	Lot 1 Basal	Lot 2 Basal & 6% dried corn distillers' solubles	Lot 3 Basal & 12% dried corn distillers' solubles	Lot 7 Basal plus alfalfa meal	Lot 4 Basal	Lot 5 Basal & 6% dried corn distillers' solubles	Lot 6 Basal & 12% dried corn distillers' solubles
No. of pigs started	14	14	14	14	16	16	16
No. of pigs finished	7	13	14	12	15	15	15
Avg. initial weight, lbs.	22	23	23	23	21	21	21
Avg. final weight, lbs.*	196	210	223	206	152	204	216
Avg. daily gain, lbs.*	0.93	1.01	1.14	1.00	0.71	0.98	1.08
Avg. daily feed, lbs.*	3.76	3.96	4.48	4.11	2.77	3.59	3.99
Feed eaten for 100 lbs. gain, lbs.*	403.	391.	394.	411.	394.	365.	371.

* For the pigs that finished.

A. *Inadequacy of the Basal Ration*

The inadequacy of the basal ration is indicated by the death losses in Lot 1 (7 head, Table 3) and the slow growth rate of the pigs in Lots 1 and 4 (Figure 2). When the growth curves of the pigs of Lots 1 and 4 are compared, the differences in survival should be considered (Lot 1, 7 pigs out of 14; Lot 4, 15 pigs out of 16, table 3).

Post mortem examinations of the pigs that died in the basal lots revealed lesions of the intestines, pericarditis, congestion of the kidneys and pneumonia. Only gross lesions were reported by the Department of Animal Pathology and Hygiene.

The average daily gains of the pigs in Lot 4 were significantly lower ($P < .05$) than those of the pigs in the fortified lots, as determined by the analysis of variance for groups with unequal numbers as described by Snedecor (1938). A similar analysis was not made for the average daily gains of the pigs in Lot 1 which was 0.93 pounds as this figure was only for the seven pigs which survived. The inadequacy of the basal ration in Lot 1 is clearly manifested by the death loss and does not need further support from statistical analysis.

The basal ration used in this experiment contained a greater variety of natural ingredients than rations used in similar studies by several investigators and would not generally be considered an inadequate ration, but the results proved it to be. The deficiency can hardly be attributed to the amount

or quality of protein, minerals, or vitamins A or D, and for pigs weighing 100 pounds or less, assay values indicated that the riboflavin, niacin and pantothenic acid requirements were met by this ration, as were also the requirements for vitamins B_1 and B_6 as judged by the available literature.

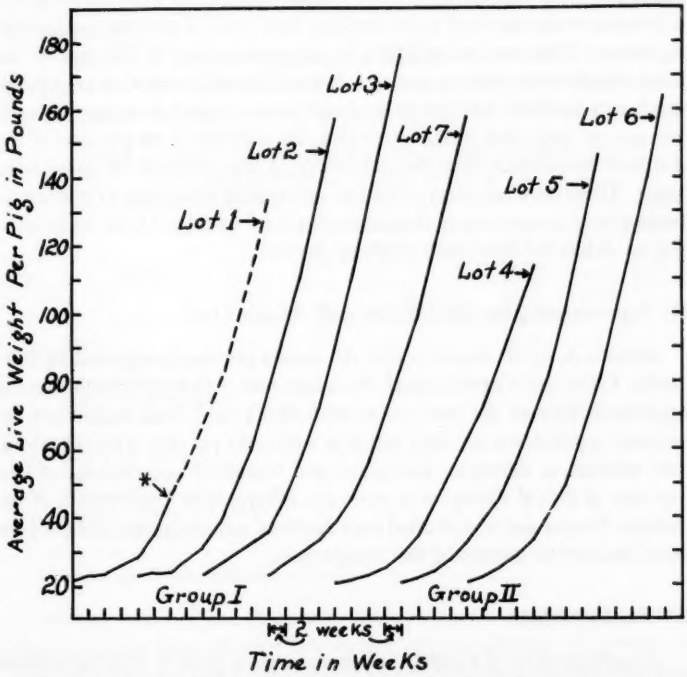

Figure 2. Growth curves of lots of growing and fattening pigs in drylot fed the basal and the basal supplemented with either dried corn distillers' solubles or alfalfa meal.

* Only 8 of the initial 14 pigs survived after the twelfth week in Lot 1.

Four possibilities are suggested in explaining the inadequacy of the basal ration: (1) the growing-fattening pig requires more of the known vitamins than the literature indicates, (2) the basal ration is deficient in other known or unknown factors, (3) the methods of vitamin assay for riboflavin, niacin and pantothenic acid are in need of greater refinement, or (4) the limiting vitamin or vitamins supplied in the basal ration are not as available to the pig as the synthetic vitamins when fed as supplements to a purified diet.

B. Supplementary Value of Dried Corn Distillers' Solubles

The addition of dried corn distillers' solubles to the basal ration increased the average daily gains, the average daily feed consumption and reduced the amount of feed consumed for 100 pounds of gain. The average daily gain per pig in Lot 3 was significantly ($P < .05$) higher than it was in Lot 2, while the differences in average daily gains between Lots 5 and 6 was not statistically significant. This may be explained by the opportunity of the pigs in the latter lots to store vitamins during lactation. The addition of 12 per cent of dried corn distillers' solubles to the basal ration induced more rapid growth and greater daily feed consumption than the addition of six per cent of the distillery by-product, but the differences in the economy of gains were slight. There does not seem to be any appreciable advantage in practice to feeding over six per cent of dried corn distillers' solubles. Death losses were low in all lots fed dried corn distillers' doubles.

C. Supplementing the Basal Ration with Alfalfa Meal

Sections A and B above confirm the results previously reported by Fairbanks, Krider and Carroll (1944). An innovation of this experiment was the supplementation of the basal ration with alfalfa meal. Such an addition apparently supplements the basal ration as well as six per cent dried corn distillers' solubles, as shown by daily gains, and was about as economical of feed per unit of gain if allowance is made for differences in fiber content of the rations. Twelve per cent of dried corn distillers' solubles appear to have been more effective in promoting live weight gain.

D. Residual Effects

A residual effect of a higher nutritional regime prior to weaning is manifested by the results of Lot 4 as compared to those of Lot 1. The pigs of Lot 1 suckled dams receiving the basal lactation ration while those of Lot 4 suckled dams receiving the basal lactation ration supplemented with dried corn distillers' solubles. Only 50 per cent of the pigs in Lot 1 survived while 94 per cent of the pigs in Lot 2 were able to live on the basal growing-fattening ration. It is noteworthy that most of the death loss occurred within ten weeks after weaning. The pigs of Lot 4 apparently stored enough of the vitamins obtained from their mothers' milk to permit them to live on the basal ration, but the storage was not enough to support as rapid gains as their litter mates receiving supplemented rations. This test indicates that weaning time to 60–70 pounds is the most important period in the nutrition of growing-fattening pigs.

E. Gross Symptoms

Posterior paralysis in swine has been frequently reported and attributed to (1) nutritional deficiencies, (2) a deficiency of certain vitamins, (3) an inadequate mineral supply or (4) fractures in the vertebrae or leg bones. Doyle (1937) presented evidence of an infectious form of "posterior paralysis" in swine.

A summary of the gross symptoms in the pigs that survived is presented in table 4. Fortification of the basal ration with dried corn distillers' solubles did not reduce the incidence of "goose-stepping," sickled hocks, and incoordination. In Lot 7, the three cases listed as "goose steppers" were much less severe than those of other lots. In fact, not a single trace of "goose-stepping" was noted in Lot 7 until after the alfalfa meal was reduced from eight to four per cent of the feed mixture. The only pig in Lot 7 which showed evidence of sickled hocks improved as the test progressed, which is not in accordance with the observations in other lots.

TABLE 4. GROSS SYMPTOMS NOTED IN PIGS DURING THE GROWING-FATTENING PERIOD

Lot No.	Treatment	No. of pigs started on test	No. of pigs died during test	No. of pigs* that "goose-stepped"	No. of pigs* with sickled hocks	No. of pigs* showing incoordination	No. of pigs* showing dermatitis	No. of unthrifty pigs in lot (close of test)
1	Basal	14	7	3	2	1	7	2
2	Basal & 6% dried corn distillers' solubles	14	1	8	2	2	9	1
3	Basal & 12% dried corn distillers' corn	14	0	6	2	3	3	1
4	Basal	16	1	3	1	1	12	6
5	Basal & 6% dried corn distillers' solubles	16	1	6	2	3	14	1
6	Basal & 12% dried corn distillers' solubles	16	1	6	2	2	7	1
7	Basal & alfalfa meal	14	2	3	1	0	5	1

* Only for the pigs that survived throughout the test.

The pigs which 'goose-stepped," first showed a stilted gait, later a slight "goose-stepping"; finally the condition became quite pronounced, and in the most severe cases the pigs struck their belly and brushed their sides with the rear legs. Affected pigs were very irritable and tired quickly when driven. With one exception, "goose-stepping" occurred among the most rapidly growing pigs, which strongly suggests that the condition might be the result of a nutritional deficiency.

Table 4 indicates less dermatitis in the pigs fed the basal ration supplemented with 12 per cent of dried corn distillers' solubles and with alfalfa

meal than among the other pigs. The incidence of dermatitis was as high in the lots receiving six per cent dried corn distillers' solubles as in the lots fed the basal ration, but the dermatitis was less severe. The pigs fed the basal ration had skins which were rough, hard, and appeared cracked about the pasterns, legs, lower hams and ears, while in some instances this condition spread over the entire body. This was described as the "elephant-hide' stage. In contrast to this condition, the pigs fed six per cent dired corn distillers' solubles were most frequently described as having dermatitis of the "raw" type, somewhat like a rash.

The alfalfa meal supplied factors known to be present in dried corn distillers' solubles. These results support the findings of Ross, Phillips, and Bhostedt (1942, 1942a) that alfalfa is a good source of many of the B-vitamins in swine nutrition.

F. Nerve Studies

Three of the "goose-stepping" pigs were autopsied by the Department of Animal Pathology and Hygiene. Microscopic lesions were not revealed but histopathological examination of the femoral and sciatic nerves prepared by Mahon's technic and by the hematoxylin-eosin method showed the presence of degeneration. This was characterized chiefly by incomplete demyelination with the medullary sheaths breaking up in droplets of myelin, and by proliferation of the Schwann cells.

Determinations of blood glucose, chlorides, creatinine, non-protein nitrogen, urea nitrogen, nicotinic acid, vitamin C, calcium, magnesium, phosphorus, Wong iron, and hemoglobin were not enlightening.

Hughes and Ittner (1942) reported "goose-stepping" as a symptom of pantothenic acid deficiency. Wintrobe, Miller and Lisco (1940) described a gait similar to "goose stepping" and nerve changes which preceded the condition. Working with purified diets, Wintrobe, Miller, Follis, Stein, Mushatt and Humphreys (1942) reported abnormal gaits and degenerative changes of the nerves on diets without calcium pantothenate or pyridoxine. When choline was omitted, some abnormalities in gaits were noted, but lesions of the nervous system were not evident in the pig. Keith, Miller, Thorp and McCarty (1942) have reported symptoms on low-manganese rations but their descriptions do not correspond with those observed in this experiment. The rations used in this trial contain from 20 to 25 p.p.m. of manganese, but Johnson (1940, 1943) obtained satisfactory growth in young pigs on rations containing even lower amounts.

Summary

The fortification of a basal lactation ration composed of yellow corn, tankage, soybean meal, alfalfa meal and minerals with six per cent dried corn dis-

tillers' solubles did not result in any important measurable difference in either pigs or sows up to weaning time.

After weaning, a basal ration composed of ground yellow corn, wheat flour middlings, soybean meal, tankage, fishmeal, fortified cod-liver oil, and minerals was nutritionally inadequate. The basal growing-fattening ration was improved by supplementing it with dried corn distillers' solubles or alfalfa meal, and the improvement is attributed to the water-soluble vitamins contained in these products. Alfalfa meal, when used as a supplement to the basal growing-fattening rations, produced as rapid growth as the addition of six per cent dried corn distillers' solubles, but not as rapid growth as the addition of 12 per cent dried corn distillers' solubles. If the gross symptoms can be attributed to nutritional inadequacy, the alfalfa meal was a more adequate supplement (at the levels fed) in promoting normal development of feet and legs than the dried corn distillers' solubles fed at the six per cent level. However, the two products were quite comparable in promoting thriftiness of skin and haircoat, especially when the solubles were fed at the 12 per cent level.

During the growing-fattening period, the pigs from the sows fed a fortified ration during lactation manifested a residual effect of the higher nutritional regime. It is postulated that the water-soluble vitamins of the distillery by-product increased the water-soluble vitamin content of the milk resulting in a storage of these factors in the bodies of the pigs, which enabled them to survive on the basal growing-fattening ration.

There was degeneration of the femoral and sciatic nerves characterized chiefly by incomplete demyelination in "goose-stepping" pigs.

Conclusions

Certain rations formulated from commonly used ingredients and adequate in protein, minerals and vitamins A and D are nutritionally inadequate for growing-fattening in drylot and may be improved for lactation. The nutritional inadequacies are in the water-soluble B_2 factors, and the known or unknown factors are supplied by dried corn distillers' solubles and by alfalfa meal. Of special significance to the farmer-feeder is the nutritional improvement following supplementation with alfalfa meal. Since normal feet, legs, gaits, skin and hair were not always obtained in the fortified lots, the possibility of further nutritional improvement is indicated. Fortification of a lactation ration with water-soluble B_2 factors results in benefit to suckling pigs which evidently store these factors to offset inadequate rations fed after weaning. This has been referred to as a residual effect.

The experiment reported in this paper was not designed to definitely indicate the factor or factors of the B_2 complex responsible for the nutritional

improvement obtained. Since assay figures suggest that the basal ration was adequate in riboflavin, niacin, and pantothenic acid for pigs weighing 100 pounds or less (the period when most difficulties were encountered) it is suggested (1) the growing-fattening pigs require more of the known vitamins than the literature indicates, (2) the basal ration is deficient in other known or unknown factors, (3) the methods of vitamin assay for riboflavin, niacin and pantothenic acid are in need of greater refinement, or (4) the limiting vitamin or vitamins supplied in the basal ration are not as available to the pig as the synthetic vitamins when fed as supplements to a purified diet.

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THE EFFECT OF SEX ON THE DEVELOPMENT OF THE PIG

III. DIFFERENCES IN GROWTH RATE BETWEEN GILTS AND BARROWS BY LINES OF BREEDING[1]

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LIVESTOCK producers are aware that among farm animals the female usually grows less rapidly during some stages of development and is somewhat smaller at maturity than the male. Whatley (1942) found the 180-day weight of Poland China males 7 pounds greater than that of females. Berge (1936) reported that a mixed group of Landrace, Yorkshire, and Landrace-Yorkshire crossbred females required 4.86 days longer than barrows to increase in weight from 20 to 90 kg. He found the sex difference in rate of gain was larger toward the end of this growth period and suggested that this was the result of growth in the female being retarded by the beginning of puberty. Knapp and Phillips (1942) stated that cattle breeders believe the sex difference to be greater in the progeny of some bulls than of others and presented substantiating evidence.

In the first paper of this series Winters *et al.* (1942) compared weights and measurements of boars and barrows. In the line designated as Minnesota No. 1[2] the differences in weight gained (barrow − boar) during four-week periods from 8 to 24 weeks of age were; −5.36, 4.78, 13.48, and 10.66 pounds, respectively. The corresponding differences in the Poland China lines were −1.37, −.86, −.07, and −.36 pounds. The contrast was explained as the result of earlier sexual activity in the Minnesota No. 1 boars than in the Poland China boars. The analysis of body measurements furnished additional evidence for such a difference between the two types of breeding. The authors suggested that early sexual activity is discriminated against by the usual methods of boar selection.

The comparison of gilts and barrows reported in this paper seemed a logical supplement to the boar-barrow comparison, particularly since data were available from the same lines. In addition, since the sex ratio in small groups of animals is subject to considerable random variation, sex differences will have an effect on comparisons of individuals based on the average performance of their pregeny uncorrected for sex. Additional information on the magnitude of the sex difference is therefore worthwhile.

[1] Paper No. 2099, Scientific Journal Series of the Minnesota Agricultural Experiment Station in cooperation with the Regional Swine Breeding Laboratory, Ames, Iowa, Bureau of Animal Industry, United States Department of Agriculture.

[2] See Winters *et al.* (1943) for the origin of this line.

Material

In contrast to the former study, gain in weight was the only measure available for analysis.

The data were, as before, on pigs of inbred lines being developed at Minnesota in cooperation with the Regional Swine Breeding Laboratory. All but a small proportion were on animals of the same seven lines used in the comparison of boars and barrows. A small additional amount of data was included from another Poland China line of special interest because of its high coefficient of inbreeding (the average was 65 percent for the pigs on which data were available). The inbreeding of the other lines ranged from 0 to 13 percent in 1938 and from 19 to 34 percent in 1941.

In the Poland China lines the gilts were compared to all males, including a small proportion of boars with the barrows. This was done for convenience and appeared justified since Winters *et al.* had found essentially no difference in the weight gained by boars and barrows of the Poland China lines. However, because it had been found that barrows of the Minnesota No. 1 line gained faster than boars the comparison in that line was between gilts and barrows only.

The numbers of animals included in the study are recorded in Table 1. They were all spring farrowed. Males and females included in the analysis were managed similarly in all lines.

TABLE 1. NUMBERS OF ANIMALS INCLUDED IN THE STUDY BY LINES AND SEX

Line	Number of animals	
	Males	Females
P.C. 1	102	100
P.C. 2	143	114
P.C. 3	137	127
P.C. 4	125	125
P.C. 5	160	159
P.C. 6	110	122
P.C. 7	41	37
Minn. No. 1	364	431
Total	1182	1215

For convenience in differentiating from the Poland Chinas as a group, the Minnesota No. 1 line will frequently be referred to as a breed.

Analysis of Data and Results

Average rate of gain to market weight. Rate of gain from weaning to 200 pounds (Comstock *et al.*, 1942) is one of the criteria of performance entered

for each pig in the records of the Minnesota swine breeding project. It was the measure of growth used in the first portion of this study.

The numbers of pigs in the sex-litter sub-classes were disproportionate, i.e., the ratio of sexes varied from litter to litter. Of the methods for analyzing variance adapted to data of this type that of fitting constants (Yates, 1934) was chosen.[3]

TABLE 2. ANALYSIS OF VARIANCE OF RATE OF GAIN IN THE POLAND CHINA LINES

Source of variation	D.F.	Sum of squares	Mean square
Sex	1	.6098	.6098
Lines	6	4.1781	.6964
Sex×lines	6	.1953	.0326
within lines			
Years	18	10.2977	.5721
Sires within years	31	4.4782	.1445
Litters within sires	189	10.7611	.0569
Sex×years	18	.4519	.0251
Sex×sires within years	31	.7038	.0227
Sex×litters within sires	189	3.9730	.0210
Pigs within sex and litter	1112	20.9176	.0188

TABLE 3. ANALYSIS OF VARIANCE OF RATE OF GAIN IN THE MINNESOTA NO. 1 LINE

Source of variation	D.F.	Sum of squares	Mean square
Sex	1	1.1546	1.1546
Years	3	3.3066	1.1022
Sires within years	15	1.4301	.0953
Litters within sires	73	3.5844	.0491
Sex×years	3	.0953	.0318
Sex×sires within years	15	.4384	.0292
Sex×litters within sires	73	1.0266	.0141
Pigs within sex and litters	411	7.2610	.0177

Data for the years 1938–1941 were included in the analyses presented in Tables 2 and 3. The pertinent mean squares are those for sex and the interactions involving sex. Primary interest in the interactions concerns their genetic implications. For example, a significant sex-sire interaction indicates variation, too great to be attributed to random sampling, in the sex differences exhibited by the progenies of different sires. Such variation would

[3] The method of expected numbers (Snedecor, 1934) was used at the beginning but was found to overestimate certain mean squares. This resulted from the very small size of the sub-classes, a rather unusual feature of these data.

logically be interpreted as the result of genetic differences among the sires. In like manner sex-litter, sex-line and sex-breed interactions would indicate genetic differences between dams, lines, and breeds, respectively. A sex-year interaction would suggest differences between the average genotypes of breeding stock used in different years.

In both analyses the mean square for sex is highly significant compared to any of the interaction mean squares or to the mean square for pigs within sex and litters; there can be little doubt that real sex differences exist. The estimated sex means are contained in table 4. The sex difference varied from −.013 to .055 in the separate Poland China lines but this variation must be construed as random since the sex-line interaction was not statistically significant. However, the mean square for the sex-breed interaction, calculated

TABLE 4. SEX MEANS* (lbs. per day)

Groups	Males	Females	Difference
Poland China	1.445	1.406	.039
Minn. No. 1	1.612	1.523	.089

* Estimated from the fitted constants according to Yates (1934).

separately and found to be .2943 was significant when compared with the sex-lines mean square within the Poland Chinas. This indicates a discrepancy between the breeds in magnitude of the sex difference, shown by reference to table 4 to be greater in the No. 1 line.

The sex-sire interaction in the No. 1 line is just beyond the five per cent level of significance compared to the mean square for the 484 degrees of freedom associated with the sex-litter interaction and the variation of pigs within sex and litter.

None of the other interactions are significant in either analysis.

Weight gained by four week periods. The magnitude of the sex effect at different ages was also studied. The analyses were based on weight gained in the four 28-day periods following weaning and were computed from the differences between the means of the males and the females in each litter rather than from the gains of individuals. Since the random variance of such differences is proportional to $((1/n_1)+(1/n_2))$, where applied to this case n_1 is the number of one sex and n_2 the number of the other in a litter, the differences were weighted by the reciprocal of $((1/n_1)+(1/n_2))$. This is in accordance with the principle of Yates' (1934) method of weighted squares of means for the analysis of data with disproportional sub-class numbers. Gains in each of the four periods were available for every pig included in the analyses. Therefore, the total weights in the period-year, period-sire, and the

period-litter sub-classes were proportional and the ordinary analysis of variance procedure could be followed. The data used were on 953[4] pigs in the first five Poland China lines and 608[4] in the No. 1 line. The data for the No. 1 line from 1939–1941 indicated a downward trend in the sex difference during the third period. Data for 1942 were, therefore, included in the analysis to furnish a partial check on the permanence of this change.

TABLE 5. ANALYSIS OF SEX DIFFERENCES IN WEIGHT GAINED BY PERIODS IN THE POLAND CHINA LINES

Source of variation	D.F.	Sum of squares	Mean squares
Periods	3	770.4	256.8
Lines	4	30.0	7.5
Years within lines	10	695.9	69.6
Sires within years	18	1474.4	81.9
Litters within sires	104	9476.4	91.1
Periods×lines	12	262.3	21.8
Periods×years within lines	30	1174.7	39.2
Periods×sires within years	54	2197.4	40.7
Periods×litters within sires	312	10,225.0	32.8

TABLE 6. ANALYSIS OF SEX DIFFERENCES IN WEIGHT GAINED BY PERIODS IN THE MINNESOTA NO. 1 LINE

Source of variation	D.F.	Sum of squares	Mean squares
Periods	3	5493.1	1831.0
Years	3	283.7	94.5
Sires within years	14	2364.1	168.9
Litters within sires	70	6750.0	96.4
Periods×years	9	2653.7	294.9
Periods×sires within years	42	2383.1	56.7
Periods×litters within sires	210	10,695.8	50.9

The analyses are contained in tables 5 and 6. Because they were computed from sex differences the mean squares for lines, years within lines sires within years, and litters within sires arise from the same sources as those for sex×lines, sex×years within lines, sex×sires within years, and sex×litters within sires, respectively in the previous analyses. Therefore, the results involving these mean squares should be in reasonable agreement. Actually all are non-significant except the one for the sex-sire interaction in the first analysis of the No. 1 line. However, the mean square for sires

[4] The majority of animals included in the previous analysis but not in this one were not weighed uniformly at four week intervals. A comparatively small number were fast growing pigs weighd out of the feed lots before gain in the fourth period had been registered; to that extent the analysis was not made on random samples of the lines. However, the authors do not believe this had an important bearing on the results of primary interest.,

within years in this analysis of that line is barely below the level of significance. When the mean square for breeds was computed for the sex difference it was found highly significant (compared to the mean square for lines within the Poland China breed) as was that for the interaction of breed and sex in the first analysis.

The mean square for periods, by comparison with that for the interaction of periods and litters, is highly significant for both breeds. This means that the variation of the mean sex differences by periods is too large to be considered entirely random. Table 7[5] shows that the sex difference increases from the first to the fourth period in both groups. The increase is greater, however, in the No. 1 line. When the mean square for the period-breed inter-

TABLE 7. AVERAGE SEX DIFFERENCES (BARROW–GILT) IN POUNDS WEIGHT GAINED BY PERIODS

Breed or line	Year	Period			
		1	2	3	4
Minn. No. 1	1939	− .20	2.16	9.88	4.26
	1940	−1.38	1.88	4.28	6.95
	1941	.19	.33	1.21	16.58
	1942	− .39	1.54	1.83	5.78
	Wtd. Av.	− .52	1.42	3.59	8.04
Poland China	Av.	.64	1.65	2.69	3.13

action was computed and compared with that for the interaction of periods and lines within the Poland China breed this difference was shown to be highly significant. The average weight gained by the Poland Chinas was 27, 40, 45, and 52 pounds in periods 1, 2, 3, and 4, respectively. The corresponding gains for the No. 1 line were 32, 44, 50, and 59 pounds. The sex difference increased at a faster percentage rate than the weight gained even in the Poland Chinas. Certainly in the No. 1 line one or more factors other than increasing gain were responsible for the increasing sex difference.

The interaction of periods and years is highly significant in the No. 1 line. Table 7 suggests this to be the result of yearly variation of the sex differences in the third and fourth periods. In order to be certain that it was not entirely the consequence of the very high value for the fourth period in 1941, the data were reanalyzed omitting that year. The interaction was still significant.

[5] This table appears in some disagreement with Table 4. However, it will be recalled that not all of the animals considered in the first analysis were involved in the second. In addition 200 pounds was frequently reached early in the fourth period with the result that rate of gain from weaning to 200 pounds represents varying amounts of the gain made in that period.

Discussion

A differential effect of sex on growth rate in the two breeds was found here as in the boar-barrow comparison (Winters *et al.*, 1942). In both cases this breed difference began at about 16 weeks of age. As before differences in age of puberty offer the most logical interpretation. Gilts of these Poland China lines were rarely if ever observed in heat prior to 168 days of age whereas in the No. 1 line the initial estrus frequently occurred between 112 and 140 days, particularly in the first two or three years. There appears to be some effect of sex on growth rate, as exhibited in the Poland Chinas, which is independent of the onset of puberty. The larger sex difference in the No. 1 line probably reflects in addition a disturbance in physiological equilibrium associated with puberty.

On the assumption that the onset of puberty retards the growth of gilts, genetic variation in age of puberty would cause interaction between sex and groups defined on the basis of relationship. It will be recalled that the only significant interaction of this type aside from the sex-breed interaction was that for sex and sires in the No. 1 line. Further analysis showed it to be statistically significant in only two years, 1938 and 1940. The line originated from a breed cross; F_1 pigs were farrowed in 1937 and F_1 boars sired the 1938 pigs. Consequently, it was surprising to find a sex-sire interaction in that year since F_1 animals are ordinarily expected to vary less genetically than individuals of other generations. Greater divergence should theoretically appear in the generations following the F_1 with still later generations becoming more uniform again as the result of selection and inbreeding. In a more detailed analysis of the 1938 data the interaction was traced to the effect of one boar that sired only one litter. Actually if one very poorly-performing barrow were eliminated from the analysis the interaction was reduced to a non-significant level. Since, in addition, the interaction in this year was barely above the borderline of statistical significance its biological significance is doubtful.

The 1939 pigs were sired largely by three F_2 boars. Therefore, a sex-sire interaction might reasonably have been anticipated. However, matings were not random. Instead each boar was mated to females less closely related to him than to the other boars. This probably tended to obscure the expression of boar differences. The interaction was significant at the five per cent level in 1940 and also in the analysis resulting from the combination of the 1939 and 1940 data. It was not significant in either 1941 or 1942.

The significant sex-sire interaction in the No. 1 line and the fact that the line was founded from crossbreds suggest the possibility of greater segregation for the sex manifestation concerned than in the Poland Chinas even

though the sex-litter interaction does not furnish supporting evidence. The possibility of change in age of sexual maturity occurring over a period of time would in that case be greater in the No. 1 line. Assuming as before that rate of growth is retarded by the onset of puberty such a change might modify the sex difference in growth rate over a period of years. However, the sex-year interaction was not significant for either breed or for any Poland China line. On the other hand the period-year interaction was significant in the analysis of gains by periods for the No. 1 line. The rather consistent decrease of the sex difference in the third period from 1939 to 1941 (Table 7) suggests that the age at which the difference is greatest was gradually increasing. It is logical to believe that such a shift might result from unconscious selection against early sexual maturity associated with the rather intense selection for growth rate that has been practiced in this line.

There is some question as to the optimum age of puberty. However, there can be little doubt that if it occurs too late reproductive performance of both sexes will be unsatisfactory in their first breeding season. In at least one of the seven Poland China lines late sexual maturity has interfered with reproductive efficiency. It appears that the possibility that selection for growth rate may have an adverse effect on age of sexual maturity deserves consideration when the development of superior lines of swine is being attempted.

Summary

Data on the growth rates of 1602 pigs from seven Poland China lines and 795 from the Minnesota No. 1 line were utilized in a comparative study of gilts and barrows.

The estimated sex difference in rate of growth from weaning to 200 pounds was .039 pounds per day in the Poland Chinas and .089 in the No. 1 line. The two were significantly different. The contrast is believed due to earlier expression of sex in the No. 1 line. The sex difference is large enough at least in the Minnesota No. 1 line so that it should be considered in progeny comparisons.

There was no indication of non-random variation in the sex differences within the Poland Chinas; none of the interactions involving sex were significant.

A sex-sire interaction, significant at the five per cent level, suggests the presence in the No. 1 line of a segregation of genes concerned with the effect of sex on the growth rate.

The sex difference in growth rate increased with age in both groups. However, the increase was significantly greater in the No. 1 line.

The analysis of sex differences by periods in the No. 1 line revealed a sig-

nificant period-year interaction that appeared to be the result of a shift in the age at which the greatest sex difference occurred.

Implications regarding the effect of selection for growth rate on age of puberty were discussed.

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A VARIABLE PHYSIOLOGICAL FACTOR NECESSARY FOR THE SURVIVAL OF BULL SPERMATOZOA[1]

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IN RECENT years many investigators have endeavored to prolong the life of mammalian spermatozoa in vitro by nutritional or other variations of their surrounding media. Although careful consideration of the composition of the media is of utmost importance, under certain conditions there are indications that an additional factor (or factors) correlated with the ability of the cell to withstand adverse environmental conditions is involved.

That this additional factor exists was first suggested by the failure of spermatozoa collected from range bulls in Arizona during 1939 to survive for more than 24 hours under controlled conditions, while under similar conditions spermatozoa collected from bulls in Missouri would survive for periods of several days. The existence of this factor was also indicated by the elimination of the differences in storage potentialities of these spermatozoa through the addition of egg yolk diluter. Further evidence for the existence of a factor (or factors) affecting the resistance of bull spermatozoa to adverse conditions has been previously presented by Lasley, Easley and Bogart (1942), Easley, Mayer and Bogart (1942), and Lasley and Bogart (1943).

These observations suggested that the presence or absence of some physiological factor might explain the general effect of egg yolk diluter on spermatozoa and the anomalous behavior of bull spermatozoa collected in different localities when placed in this medium. The initial endeavor in the investigation of the factor was a study of the behavior under adverse conditions of ejaculated and epididymal spermatozoa with and without the addition of the egg yolk diluter.

Materials and Methods

The semen used in this investigation was collected with an artificial vagina from three beef bulls in Missouri and from six range bulls in Arizona.[2] Seven additional range bulls in Arizona were castrated and the epididymal spermatozoa immediately recovered by flushing the tail of the epididymis with M/8 phosphate buffer solution.[3] (M/8 phosphate buffer was also sub-

[1] Missouri Agricultural Experiment Station Journal Series No. 893.

[2] San Carlos Indian Agency, San Carlos, Arizona.

[3] Isotonic with bull seminal plasma (Easley, Mayer, and Bogart, 1942).

stituted in the preparation of the egg yolk diluter as described by Phillips (1939).)

The resistance of the spermatozoa to adverse conditions was estimated by subjecting them to a cold shock of 0° C. for 10 minutes, and then determining the number of surviving cells by the staining method of Lasley, Easley and McKenzie (1942).

Experimental

Comparative survival time of the spermatozoa.—A striking observation in this investigation (confirming those previously reported from this laboratory) was the inability of spermatozoa from the bulls in Arizona to survive under controlled storage conditions without the addition of egg yolk-phosphate diluter. This differed from most observations previously reported by other investigators on the survival of bull spermatozoa under storage conditions. The lack of the ability of the spermatozoa obtained from the bulls in Arizona to survive is demonstrated by the low percentage of the total spermatozoa in the 22 samples studied capable of withstanding storage conditions for more than 18 hours. Furthermore, as shown in table 1, all the spermatozoa of these 22 samples were dead after 144 hours. On the other hand, when portions of these semen samples were diluted with egg yolk-phosphate diluter, an average of 62.3 per cent survived the 144-hour storage period. In comparison, in semen collected from bulls in Missouri and stored without egg yolk, an average of 34.5 per cent of the spermatozoa were alive at the end of the 144-hour period and in none of these samples did less than 18 per cent of the spermatozoa fail to survive. Even though the survival capacity of these spermatozoa exceeded that of the spermatozoa from bulls in Arizona, the addition of egg yolk-phosphate diluter was beneficial as shown in table 1. Interestingly, as shown in table 1, little difference existed in the average percentage of live spermatozoa in the diluted semen of the bulls in both localities at the end of the storage period.

Comparative resistance of ejaculated spermatozoa to temperature shock.—In an endeavor to measure the resistance of the spermatozoa to adverse environmental conditions the cold-shock technique was developed. The results obtained by this method within 15 to 20 minutes after the collection of the semen were comparable to those obtained by storage for a period of 144 hours, as indicated in tables 1 and 2. Again, as in the storage experiments, the ability of the spermatozoa in undiluted semen to survive under adverse conditions was considerably less in the samples collected in Arizona. Also, as in the storage experiments, the difference in the resistance of the spermatozoa from bulls of the two localities was eliminated by the addition of egg yolk diluter.

The data in Tables 1 and 2 are representative of results obtained in an extensive investigation of the survival of spermatozoa under varying conditions demonstrating the effects of egg yolk-phosphate diluter on spermatozoa.

TABLE 1. PERCENTAGE OF LIVE SPERM AFTER STORAGE IN SEMEN COLLECTED FROM BULLS IN MISSOURI AND ARIZONA
(stored 144 hours at 8–10° C.)

	No. of Sample	% live sperm in non-diluted semen	% live sperm in semen diluted 3:1 with E. Y. diluter
Arizona	1	0	34
	2	0	45
	3	0	64
	4	0	51
	5	0	61
	6	0	74
	7	0	71
	8	0	70
	9	0	78
	10	0	44
	11	0	55
	12	0	72
	13	0	67
	14	0	57
	15	0	79
	16	0	64
	17	0	74
	18	0	68
	19	0	63
	20	0	78
	21	0	55
	22	0	66
	Avg.	0	63.2
Missouri	1	35	58
	2	33	55
	3	23	61
	4	18	55
	5	40	61
	6	58	77
	Avg.	34.5	61.1

In no case, using either the storage or the cold shock methods, did this diluter enable 100 per cent of the spermatozoa to survive. In all cases the percentage of spermatozoa surviving in the yolk-phosphate diluter was approximately the same. The latter observation indicates that some of the spermatozoa are not receptive to the protective action of the egg yolk diluter.

TABLE 2. PERCENTAGE OF LIVE SPERM AFTER 10 MINUTES AT 0°C. IN SEMEN COLLECTED FROM BULLS IN MISSOURI AND ARIZONA

	No. of Sample	% live sperm non-diluted semen	% live sperm in semen diluted 3:1 with E. Y. diluter
Arizona	1	3	57
	2	14	70
	3	15	67
	4	7	68
	5	0	12
	6	4	56
	7	14	21
	8	2	50
	9	3	34
	10	4	66
	11	5	61
	12	7	61
	13	1	9
	14	9	65
	15	2	29
	16	2	77
	17	5	45
	18	4	40
	19	3	58
	20	1	53
	21	5	63
	22	3	45
	Avg.	5.1	52.1
Missouri	1	47	56
	2	47	56
	3	31	35
	4	20	51
	5	40	42
	6	54	80
	7	63	70
	8	57	63
	Avg.	44.9	59.1

Comparative resistance of epididymal and ejaculated spermatozoa.—Previous investigators have shown that mammalian spermatozoa will survive for more than 20 days in the epididymis, Young (1929); Hammond and Asdell (1926), and that epididymal sperm will survive for a longer period in vitro than ejaculated spermatozoa, Gonzaga and Valenzuela (1934); Bretschneider (1936). The greater capacity of epididymal spermatozoa to retain their viability suggested that they might be more resistance to adverse environmental conditions then ejaculated spermatozoa. The ability of epididymal

spermatozoa from bulls in Arizona to survive a cold shock was measured and found to be considerably greater than that of freshly ejaculated spermatozoa both in non-diluted semen and in semen diluted with egg yolk diluter (table 3).

TABLE 3. COMPARATIVE RESISTANCE* OF EPIDIDYMAL SPERM AND EJACULATED SPERM TO A COLD SHOCK
(Arizona bulls)

Source and treatment of sperm	No. of samples	Percentage of live sperm 0° C.	
		Mean	Range
Tail of epididymis	7	79.6	73–86
Ejaculated semen	124	11.7	0–40
Ejaculated semen diluted with E. Y. Diluter	82	52.3	10–80

* Resistance was measured immediately following collection.

Discussion

Whether egg yolk-phosphate diluter would prolong the survival of bull spermatozoa has been controversial since Phillips (1939) first recommended this diluter for the storage of semen. Several investigators, Easley, Mayer and Bogart (1942); Underbjerg, Gravers and Davis (1940); Swanson and Herman (1940), have shown that egg yolk was unnecessary for the satisfactory storage of bull semen, whereas other investigators, Phillips and Lardy (1940); Salisbury, Fuller and Willett (1940), and Easley, Mayer, and Bogart (1942) have stressed the necessity of this diluter. The data presented in this paper point to the resistance of the spermatozoa against adverse environmental conditions as the primary requisite for survival and may explain these contradictory results.

The relationship between resistance and survival is demonstrated by the results reported in Tables 1 and 2. Spermatozoa obtained from bulls in Arizona lacked the ability to survive under storage conditions. The resistance of these spermatozoa to a cold shock was also extremely low, but in the presence of egg yolk, the ability of these cells to withstand both the storage conditions and cold shock was vastly improved. This relationship is further demonstrated by the results obtained in Missouri. Resistance and survival under storage conditions were considerably greater in the spermatozoa collected from the Missouri bulls and led one to believe that the addition of egg yolk was unnecessary; nevertheless, in all cases the addition of egg yolk did improve the capacity of some of these spermatozoa to survive a cold shock and storage. Our observations (Tables 1, 2, 3) that bull spermatozoa vary in their capacity to resist adverse environmental conditions, would indicate that if a

large percentage of the spermatozoa in a semen specimen is resistant, these spermatozoa survive without the addition of egg yolk; whereas, if the number of resistant spermatozoa is extremely low, the addition of egg yolk is essential for survival (Lasley, Easley and Bogart, 1942; Easley, Mayer and Bogart, 1942; Lasley and Bogart, 1943).

Survival of bull spermatozoa has been shown to be dependent primarily upon a variable physiological factor which is responsible for their resistance to adverse environmental conditions as measured by storage and cold shock. The variations in the ability of bull spermatozoa to survive under these conditions are governed by two circumstances; namely, the resistance of the cells at the time of ejaculation and the ability of the cells to acquire resistance after ejaculation—the number of spermatozoa surviving in nondiluted semen is dependent upon the first, and the number surviving in egg yolk is dependent upon the second. The data in table 3 indicate that many spermatozoa are resistant in the epididymis but lose this resistance when ejaculated. However, a number of the ejaculated spermatozoa, which varied with locality and individual ejaculates, retain their ability to acquire resistance and are capable of becoming resistant in the presence of egg yolk.

Summary and Conclusions

Data have been presented showing that the survival of bull spermatozoa is dependent primarily upon a variable physiological factor which is responsible for or influences their resistance to adverse environmental conditions.

Further, these data show that a relationship exists between the survival time of bull spermatozoa under storage conditions and the degree of their resistance to a low temperature shock. The cold shock technique, then, can be utilized as a measure of the storage potentialities of semen specimens.

Results obtained in this investigation suggest that the storage potentialities of undiluted semen are dependent upon the number of resistant spermatozoa present at the time of ejaculation. On the other hand, they suggest that the storage potentialities of semen diluted with egg yolk are dependent upon the number of spermatozoa, in addition to those resistant at ejaculation, possessing the ability to become resistant in the presence of egg yolk.

The epididymal spermatozoa were much more resistant to a cold temperature shock than ejaculated spermatozoa. Apparently, a varying proportion of epididymal spermatozoa lose their resistance by the time they are ejaculated, but some of the ejaculated spermatozoa still possess the faculty of becoming resistant.

A marked difference was found, both in the survival during storage and in the resistance to a low temperature shock, in spermatozoa obtained from the three bulls in Missouri and those obtained from the six bulls in Arizona.

This regional difference in resistance exceeded that found to exist between the spermatozoa of semen specimens from an individual bull or from different bulls in the same locality. However, these differences were largely eliminated by the addition of egg yolk-phosphate diluter. Further investigations are in progress to ascertain the cause and significance of these individual and regional differences.

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STUDIES WITH SWINE ON LOW-MANGANESE RATIONS OF NATURAL FOODSTUFFS[1]

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THE SATISFACTORY growth of swine from an early age on a ration extremely low in manganese was described by Johnson (1940, 1943). The dry basal ration of semisimplified type, which was fed with liquid skimmilk, contained 3.2 per cent of ash and 0.27 ppm. (parts per million) of manganese. Satisfactory reproduction was obtained on this ration when the dry feed contained 10 per cent of "Cerogras," which necessarily raised the manganese content to 6 ppm.

Keith, Miller, Thorp, and McCarty (1942) observed a type of stiffness in 50 per cent of pigs on a ration of corn tankage, soybean oil meal, suncured ground alfalfa hay, and salt. This condition was prevented, but not cured, by supplementing the ration with manganese. Initially the pigs weighed 70 to 100 pounds, and the stiffness developed at about 150 pound weights. The authors point out the similarity of their rations as regards ash and manganese content (6 to 9 per cent and 11 to 14 ppm. respectively) to rations of natural foodstuffs producing perosis in chicks.

Since the rations used by Johnson (1943) are not likely to be duplicated in actual practice and were not strictly comparable to those used by Keith, *et al.*, experiments were carried out, making use of natural foodstuffs of low manganese content, with the results presented.

Material and Methods

The rations used are described in table 1. Rations 75 and 76 were patterned after those used by Keith and associates (1942). The high ash content was obtained by the use of high-ash meat scrap and steamed bone meal. Ration 77 was similar except for reduction in ash content by omission of the bone meal and substitution of 60 per cent protein tankage for the 50 per cent meat scrap. Since rations of this composition may be deficient in organic factors preventing stiffness (Ellis and Madsen, 1941) skimmilk powder and brewers' yeast were included in rations 75, 76, and 77, which were fed ad libitum, with fresh tap water[2] to drink. Rations 86, 87, 88, and 89, consisting mainly of yellow corn without or with supplements of bone meal and manganese, were fed with liquid skimmilk according to appetite.

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[2] Analysis showed the tap water to contain .0012 ppm. of manganese.

The dams of the litters designated groups 1 and 3 in table 2 were limited to ration 86 plus skimmilk, so that previous to beginning the experimental feeding these pigs did not have access to a reliable source of manganese. Pig 21 in group 2 which was placed on the high manganese high-ash ration 76 came from a dam on a high manganese ration, while the others in this group were from dams on low manganese rations.

TABLE 1. COMPOSITION OF RATIONS

Ration No. Type	75 Low Mn-High Ash "LM-HA"	76 High Mn-High Ash "HM-HA"	77 Low Mn-Medium Ash "LM-MA"	86 Low Mn-Low Ash "LM-LA"	87 Low Mn-High Ash "LM-HA"	88 High Mn-Low Ash "HM-LA"	89 High Mn-High Ash "HM-HA"
Yellow corn meal, lb.	69.5	69.5	76.5	99.5	89.5	99.5	89.5
Vitamin D yeast,[1] lb.	1	1	1	0.5	0.5	0.5	0.5
Brewers' yeast, lb.	2	2	2				
Steamed bone meal, lb.	5	5			10		10
Manganese,[2] mg. per kg.		200				100	100
Dehydrated alfalfa leaf meal lb.	5	5	5				
Skimmed milk powder, lb.	5	5	5				
Meat scrap (50% protein), lb.	12	12					
Tankage (60% protein), lb.			10				
NaCl, lb.	0.5	0.5	0.5				
Analysis, oven dry basis							
Ash, per cent[3]	10.91	11.19	5.15	1.78	12.31[5]	1.77	13.41[5]
Manganese, mg. per kg.[4]	7.47	228.68[5]	7.73	8.60[5]	10.05[5]	128.03[5]	128.53[5]

[1] Contains 112.5 units vitamin D per gram. This was omitted in the earlier part of the work, when sunlit concrete porches were used.

[2] Added as the C. P. sulphate salt in solution.

[3] Ashed at 600° C. for 6 hours, then 800° for 1 hour or until all carbon was consumed.

[4] By the periodate method of Willard and Greathouse (1917) with modifications suggested in private communication from Dr. P. J. Schaible.

[5] These analyses, while correct for the available samples, are undoubtedly high for the average feed consumed.

With the exception of the group 1 litter all animals were confined indoors, with access only to concrete and wood. The pens used for the group 1 litter were of concrete but had galvanized iron pipe partitions, and outside concrete sunporches. No bedding was used during the growth trials. A small amount of hardwood sawdust was used for the young litters in the reproduction studies.

Results and Discussion

Since the special quarters necessary for this type of work limited the number of animals used, considerable care was exercised in the selection and division of the animals. All animals were from one line and the group 1 and

TABLE 2. GROWTH, AND MANGANESE STORAGE IN THE LIVER OF PIGS RECEIVING DIFFERENT LEVELS OF MANGANESE AND ASH

Pig No.	Dam's ration No.[1]	Ration		Initial age	Initial weight	Final weight	Mn in dried liver	
		No.	Type	days	pounds	pounds	mgs./kg.	mgs.
group 1, littermates, 168-day feeding period								
41-169 M	86	control		56	21½		8.50	0.54
-161 F	86	86	LM-LA	56	34	220	6.43	3.11
-162 F	86	86	LM-LA	56	30	225	see table 4	
-160 F	86	77	LM-MA	56	33	245	9.69	5.11
-164 F	86	77	LM-MA	56	23½	233	9.74	3.89
-160 M	86	75	LM-HA	56	30	213	8.79	4.40
-166 F	86	75	LM-HA	56	27	184	10.63	4.02
-167 F	86	75	LM-HA	56	35	183	9.08	4.10
-163 F	86	76	HM-HA	56	30	190	13.41	6.51
-165 M	86	76	HM-HA	56	28	258	13.54	6.31
-168 F	86	76	HM-HA	56	35	236	11.88	6.35
group 2, from 3 litters,[2] 133-day feeding period								
41- 7 F	51[3]	75	LM-HA	106	76	215	7.25	3.50
- 33 M	49	75	LM-HA	100	45	206	7.63	4.25
- 21 F	50	76	HM-HA	101	82	262	11.24	5.94
- 6 F	51	76	HM-HA	106	53	178	9.05	3.66
group 3, littermates,[4] 161-day feeding period								
42-160 M	86	control		50	18		6.53	0.32
-161 M	86	86	LM-LA	50	21	234	7.33	3.26
-165 F	86	86	LM-LA	50	19	202	7.30	2.82
-162 F	86	87	LM-HA	50	22	215	4.13	2.20
-169 F	86	87	LM-HA	50	28	230	6.82	2.95
-163 M	86	88	HM-LA	50	19	217	13.30	5.78
-168 F	86	88	HM-LA	50	20	214	12.28	5.92
-166 F	86	89	HM-HA	50	22	193	14.52	5.93
-164 F	86	89	HM-HA	50	27	217	14.27	6.51

[1] Pigs had access only to dam's ration before trials began.

[2] These three litters out of litter mate dams and by the same sire.

[3] See JOURNAL OF ANIMAL SCIENCE 2: 14–22.

[4] The dam of these pigs is No. 162 F listed above.

group 3 pigs represent the first and second generation of one sow. These two litters were large and the individuals were uniform in size. This, plus precautions to prevent manganese intake during the suckling period and initiating experimental feeding early in life, tended to make the animals on the various rations within the groups, and especially within groups 1 and 3, uniform initially with respect to genetic make-up, size, and nutritional status. Since there were few animals on each ration within each group, variation is best examined by inspection of the individual gains and manganese storage during growth. These data are presented in table 2.

In group 1, rations 75, 76, and 77 were compared, and in addition two pigs were continued on the dam's ration of yellow corn and liquid and skimmilk (No. 86). The liver analysis of the control pig in this litter shows that there was an appreciable store of manganese initially in spite of the precautions taken. Immediately after starting the experiment it became apparent that the high-ash rations 75 and 76 were not appetizing, whereas the pigs on the similar ration of lower ash content, No. 77, and those on the corn-skimmilk ration relished their feed and started well. While those on the high-ash rations eventually came into feeding well they never showed the liking for their feed that the other pigs did. Feed refusals were frequent on the high-ash rations, and particularly on ration 75. Since the combined gain of the 3 pigs on ration 76 was over 100 pounds greater than that of those on ration 75 it seems reasonable to conclude that added manganese improved the high-ash ration used in this work. While the differences in gains are not great the behavior of the pigs toward their feed and the gains are in agreement that the ration of natural foodstuffs of medium ash content (No. 77) is the most satisfactory of the rations used in this work for growing pigs.

Very little difference in appetite or gains was noted among the animals of group 2 in which the effect of supplementing the high-ash ration with manganese was again compared. Initial weights and previous feeding treatment of these pigs were not as uniform as for the other groups. Pig 21 F was from a litter of two and extremely growthy and thrifty throughout life.

Some stiffness occurred in all pigs from time to time but was never severe enough to interfere with locomotion and not noticeably different between lots.

The results of the manganese analyses of the livers were surprising in that all showed ample stores of manganese. Liver storage of manganese paralleled the manganese intake, without apparent effect from the ash content of the ration.

The basal ration for pigs in group 3 was yellow corn, irradiated yeast, and skimmilk. Regardless of whether or not bone meal or manganese was in-

cluded in this ration, the pigs showed good appetite throughout and made uniformly satisfactory gains. However, on the basis of the limited data, it appears that the supplement of 10 per cent of bone meal was associated with a slightly lower liver manganese storage.

On all rations of natural foodstuffs used in this work manganese storage was greater than that formerly found in swine of similar size on semisimplified rations of extremely low manganese content (Johnson, 1943).

Reproduction trials were carried out only with ration 86. The litter records are shown in table 3.

TABLE 3. REPRODUCTION ON A RATION OF YELLOW CORN, IRRADIATED YEAST, AND SKIMMILK

Litter No.	Dam			Litter Record			
	No.	Age	Time on ration before farrowing	No. of pigs		Weaning	
				Born	Weaned	Age	Ave wt.
		years				*days*	*lbs.*
41-160	39- 61	2	1 week	11	11	41	22.6
42-160	41-162	1	all life	10	9	49	21.7
42-170	41-162	1½	all life	11	9	58	27.3
43-250	42-176	1	all life	11	9	56	18.0
43-240	42-175	1	all life[1]	7	7	57	19.9

[1] Except for 60 days after weaning when 10 per cent "Cerogras" was added to the dry ration.

Dams 42–175 and 42-176 are from dam 41-162 which in turn is from dam 39-61. Thus the pigs of dam 42-176 represent the fourth generation of animals on a ration of corn, vitamin D supplement, and skimmilk without interruption.

The pigs in the first three litters grew well and remained sleek and fat throughout the nursing period. Litter size is somewhat above, and growth rate fully comparable to, the average for the station herd. Hemoglobin readings were taken periodically. Anemia was not severe, very few readings below 50 per cent Hb. being obtained. This was probably due to the large size of the litters which led to the pigs beginning consuming corn at three weeks of age. Since the author has observed that pigs with Hb. values of 20 per cent and even lower for a short time survive and grow normally if they have access to dry feeds, iron medication with resultant slight manganese contamination was not resorted to in this work.

All sows have had good udder development and appeared to be giving plenty of milk throughout the lactation periods. All sows have shown normal mother instinct. All pigs alive at birth were strong and nursed immedi-

ately. One pig in litter 42-160 and two pigs in litter 42-170 were born dead.

Occasional stiffness and tender-footedness have been observed in the sows, not severe enough to prevent fairly normal activity and freedom of locomotion at any time. It cannot be stated whether this trouble is due to dietary deficiency, the rough concrete floors, or possibly to erysipelas which is present on the farm.

Dams 42-175 and 42-176 are somewhat undeveloped in thickness of body and bone for age. They farrowed normally at one year of age, one day apart in the fall of 1943. They appeared to lactate well and the pigs were of very good appearance till five weeks of age, at which time signs of nutritional deficiency appeared rather suddenly. The pigs became rough haired and arched backed, though they still appeared to get all the sow's milk they desired. Anemia was not severe and the Hb. levels were rising during the two

TABLE 4. MANGANESE ANALYSES OF PIGS BORN DEAD IN LITTER 42-170, AND OF LIVER OF SOW AFTER WEANING LITTER

Animal	Body wt.	Mn in dried liver		Mn in dried body[1]	
	lbs.	*mgs./kg.*	*total mgs.*	*mgs./kg.*	*total mgs.*
pig born dead	2.47	5.80	.022	2.60	.464
pig born dead	1.51	4.58	.036	2.08	.258
Sow 41-162	403	3.79	2.395		

[1] Exclusive of liver.

previous weeks. Manganese deficiency may have been involved here though pigs had previously been raised under more stringent conditions in this regard (Johnson, 1943). The most likely explanation of the nutritional difficulty appears to be in the quality of the skimmilk. There had been a severe drouth and shortage of pasture for the dairy herd during the summer and fall, which no doubt affected the vitamin content of the milk (Elvehjem *et al.*, 1934). Several possibilities are being investigated.

Manganese analyses of the livers and whole bodies of the two pigs born dead in litter 42-170, table 4, show significantly more manganese storage than reported for new-born pigs of dams on extremely low manganese intake, but considerably less than found for pigs from dams on high manganese intake (Johnson, 1943). The subsequent analysis of the liver of the dam of these pigs showed an ample store of manganese, similar to that of sows on a manganese supplemented ration previously reported. No significant reduction in manganese storage in this case was brought about by long continued feeding of yellow corn and skimmilk.

There is little doubt that manganese in small quantities is essential to adequate swine nutrition but this has not been clearly demonstrated, even with

the long continued use of rations containing less manganese and in some cases much more ash than is found in actual practice. From these results it appears unlikely that manganese deficiency will occur under conditions of normal swine practice where pigs have access to soil or manganese-carrying feeds such as oats, bran, shorts, or forages.

Summary

Pigs have been grown at satisfactory rates from weaning to butcher weights on rations of natural foodstuffs containing 7 to 10 parts per million of manganese. When the ash content of these rations was raised to over 10 per cent there appeared to be a slight beneficial effect from the addition of manganese, though the ratio of medium ash content, which was not supplemented with manganese, appeared to be the most satisfactory of those used.

Reproduction on a ration of corn and skimmilk, with vitamin D supplement, was satisfactory through two generations.

Manganese storage in the liver and body of animals on rations of natural foodstuffs of low manganese content is greater than that previously found for animals on a very low manganese ration of semi-implified type.

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FEED UTILIZATION TESTS WITH CATTLE

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Introduction

IN FEEDING experiments with steers, Winters and McMahon (1933) found a high correlation between rate of gain and efficiency of feed utilization. Grade was found to be highly correlated with price per pound and this factor and efficiency of feed utilization contributed about equally to net profit. These workers proposed a system for recording performance of beef cattle based upon rate of gain to 12 months of age as a measure of efficiency and grade as a measure of value per pound. Black and Knapp (1936) also found a high correlation between rate of gain and economy of gain.

Kleiber (1936) in discussing problems involved in breeding for efficiency of food utilization pointed out that there was no fundamental relationship between body size and efficiency of food utilization. He further showed that absolute rate of gain could be used as a measure of efficiency only when comparing animals of the same size. Relative food capacity[2] was indicated to be a major determinant of total efficiency and relative gain a good index of relative feed capacity. Relative gain and food capacity were defined as rate of gain or food intake per unit of metabolic body size. The $\frac{3}{4}$ power of body weight was regarded as an adequate expression for metabolic body size.

Brody (1939) concurred with Kleiber in the view that energetic efficiency may not depend on body weight but pointed out that there may be less management overhead involved in producing the same amount of product from fewer animals of large size than from a larger number of small animals.

In conducting tests on economy of gain of cattle, Black and Knapp (1936) used a procedure of weaning calves at 252 days and feeding to a constant weight of 900 pounds. Apparently this was changed, for later in the publication it is mentioned that the calves were weaned at 500 pounds regardless of age and fed to a weight of 900 pounds. In tests on range-raised calves, Knapp *et al.* (1942) fed them from time of weaning at about 180 days of age until they weighed approximately 900 pounds. Similar tests by other workers have been run for a definite number of days.

If feed utilization tests are to be extensively employed as a part of performance records, the procedure must be relatively simple. Obviously calo-

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[2] Relative feed capacity should not be considered merely capacity of the gastro-intestinal tract although this may be involved. Digestion, absorption and storage capacities as influenced by internal stimuli for growth and development are considered to be fundamentally concerned. These, together with the body temperature regulating capacity, are factors influencing appetitite. See scheme of energy utilization (Kleiber, 1936).

rimetry or slaughter experiments are impractical for this purpose. If efficiency of feed conversion is to be studied independently of type, size, and earliness of maturity variations, some means of approximate control of the composition of the gain appear necessary.

With these considerations and concepts, neither feeding for a definite period of time nor from a definite age or initial weight to a definite final weight appear adequate. These procedures seem liable to lead to results difficult to interpret because of variation in energy content of gain. Practical stockmen are interested in the feed cost necessary to produce a degree of finish meeting the requirements of a definite market grade as evidenced by their practice of "topping out" individuals for sale when they have reached the desired stage. For feed utilization tests, the practical approach of starting at weaning time, which is more or less fixed by length of lactation period, and of "topping out" as the animals attain a desired degree of finish, appears to be scientific from the standpoint of both nutrition and growth. Accordingly we decided to investigate the possibility of measuring efficiency of feed utilization under the following conditions:

1. Feeding a standard ration according to appetite.
2. Marketing the individuals from the various lots when they attained a definite degree of finish as judged from their appearance.
3. Recording conformational variations by means of measurements, grading and carcass data.

Experimental

Four gets of sire each consisting of ten head of steer calves were purchased from cattlemen cooperating with the University in the beef-cattle breeding project. The sires were University bred-and-owned bulls lent to the cooperators under an agreement. The plan was to select calves of uniform size and age. Due, however, to the limited number of steer calves available considerable variation of age and weight had to be accepted for the sake of securing ten head, and there was some variation in the average age of the different lots. The calves were brought to Davis, November 1, 1941, and started on a light grain ration and a full feed of hay. Lots 3 and 4 had to be dehorned; the remaining two lots had been treated with caustic at an early age. The setback of dehorning under these conditions abount to 34 pounds per head less gain during the preliminary period, and the cost of the cattle was increased $.70 per hundredweight. The calves continued on the preliminary ration until all had recovered and become adjusted to their environment. On December 9 the test began. Weights were taken on three successive days at the beginning and at the time of marketing, and single weights were taken at intervening intervals of 25 to 35 days.

TABLE 1

Summary of Feed Utilization Experiment with Steer Calves
Sired by Bulls 505, 587, 608, and 632

(Ten steers in each lot. Unless otherwise designated, figures are in pounds)

Lot number	1	2	3	4
Sire number	505	587	608	632
Length of feeding period, days	161.5	169	169	166.5
Average initial weight	528	539	430	467
Average final weight	871	871	779	787
Total gain per steer	343	332	349	320
Average daily gain	2.13±.04	1.96±.06	2.06±.09	1.92±.08
Average relative gain,[1] grams/kg.$^{3/4}$	12.8 ±.33	11.7 ±.29	14.0 ±.36	12.7 ±.49
Average daily ration				
Rolled barley	6.0	5.9	5.5	5.5
Molasses beet pulp	3.5	3.4	3.2	3.1
Cottonseed meal	0.5	0.49	0.46	0.46
Alfalfa hay	7.4	7.1	7.1	6.6
Total for each 100 pounds live weight	2.5	2.4	2.7	2.5
Relative feed capacity,[1] grams/kg.$^{3/4}$	105	101	111	103
Per cent concentrates	57.5	58.0	56.2	57.7
Per cent roughage	42.5	42.0	43.8	42.3
Feed per 100 pounds' gain				
Rolled barley	282	300	265	287
Molasses beet pulp	165	175	155	159
Cottonseed meal	24	25	22	24
Alfalfa hay	348	364	344	345
Total concentrates	471	501	442	470
Total of all feed	819	864	786	815
Efficiency of feed utilization, lot 3 = 100	96	91	100	96
Live grade, per cent	83.5	82.6	85.0	85.3
Carcass grade, per cent	85.9	85.6	84.7	87.1
Dressing, per cent[2]	59.3	60.2	59.3	59.6

[1] Average relative daily gain and relative feed capacity are expressed in grams' gain or feed intake per unit of metabolic body size. The metabolic size was derived by averaging the three-fourths powers of the mean weights for each of the six periods. The difference between this calculation and that derived from the three-fourths power of the mean of the initial and final weights was not significant.

[2] Dressing percentage is based upon full weight in the feed lot (average of 3 daily weights) less 4 per cent shrink and cold carcass weights.

All cattle received a concentrate ration mixed and fed from the same batch. As they came on feed, the proportion of roughage to concentrates was kept constant for all lots. After they were on full feed (60 per cent concentrates), hay was given in excess of consumption, and that refused was weighed back at frequent intervals. Whenever the hay consumption increased in any lot so that the hay:concentrate ratio became greater than

40:60 concentrates were increased. Thus the animals could express their appetites, and reliance on judgment was minimized.

An approach was made to marketing at equal finish by selling in two drafts. Since more frequent marketing proved impracticable, there were significant differences in the finish of some individuals. The average for each group, however, was reasonably similar.

Table 1 gives the feeding-trial data.

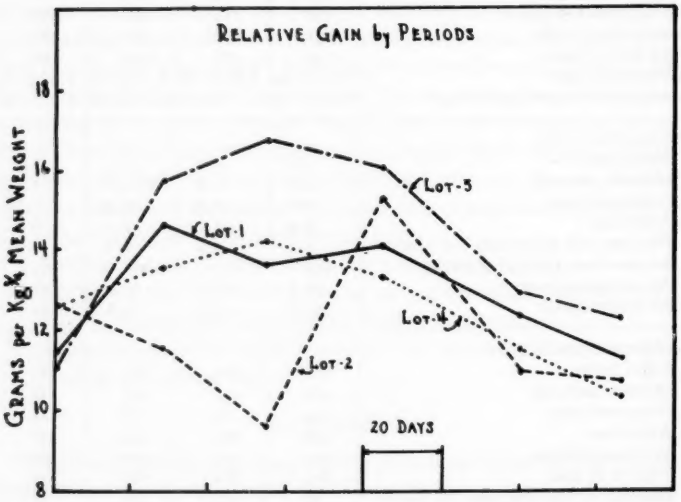

Figure 1. Average relative gain of the four lots for each weighing period.

The steers in lots 1 and 2 probably averaged about a month older than those in lots 3 and 4 and were in slightly better condition at the start. At the end of 149 days, five steers were marketed from lot 1, two from lot 2; two from lot 3; and three from lot 4. The remaining steers from all lots were marketed after 174 days. Table 1 gives the average feeding period.

Lot 3 was handicapped by two very young steers. The average final weight of the other 8 head was 814 pounds; the average daily gain was $2.13 \pm .06$ pounds. These two young steers that were not well finished also affected the average grade and to a slight extent average yield. As shown in table 1, there was no significant difference in average daily gain between lots 1 and 3 or between lots 2 and 4. The difference in average daily gain between lots 1 and 2, and between lots 1 and 4 are significant ($P = 0.05$). The difference

in average daily gain between lot 3 and lots 2 or 4 is not significant. If, however, the two younger animals in lot 3 are omitted the difference between the remaining 8 head and lot 2 or 4 is significant at the 5 percent level.

On the basis of average relative gain (gm. daily per kg.$^{3/4}$ mean weight) there was no significant difference between lots 1 and 4. The difference between lot 1 and lot 2 and between lot 1 and lot 3 is significant ($P<0.05$). The difference between lot 2 and lot 3 is highly significant ($P<0.01$). The difference in relative gain between lots 2 and 4 and between lots 3 and 4 is of borderline significance, that is, the probability (P) of random occurrence was slightly greater than 5 percent. Figure 1 shows the trend in relative gain by periods.

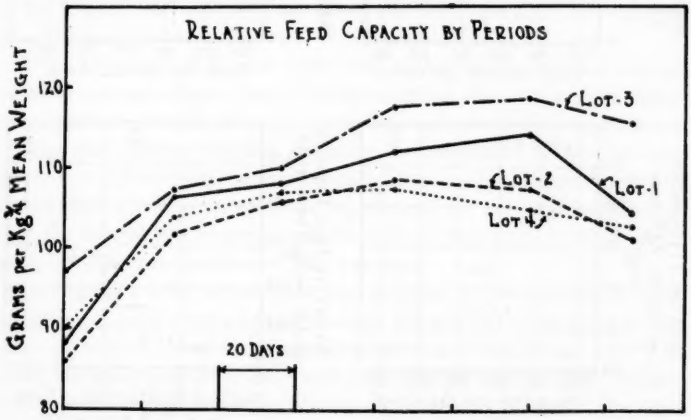

Figure 2. Average relative feed capacity of the four lots for each weighing period

As table 1 and figure 2 show, lot 3 had the greatest relative feed capacity as measured by daily feed consumed per kg.$^{3/4}$ of mean weight. On the basis of uniformity of difference between lots during the six periods, the differences between lots 1 and 2; 1 and 3; 2 and 3; and 3 and 4 are highly significant. The differences between lots 1 and 4 and between lots 2 and 4 are not significant as determined by this limited means of analysis. The feed consumed per 100 pounds of live weight was equal for lots 1 and 4 and the difference between these lots and the other two lots was consistent for each period and highly significant.

The appetite of lot 3 steers was so great that we had difficulty in increasing concentrates fast enough; the proportion of concentrates to hay over the

whole period fell somewhat below the figure for the other groups. Despite this slightly lower energy value of the ration, the economy of gain was highest in this lot. Lot 2 having the lowest relative gain and relative feed capacity showed the lowest efficiency (greatest amount of feed for 100 pounds gain) although the absolute rate of gain was the same as in lot 4.

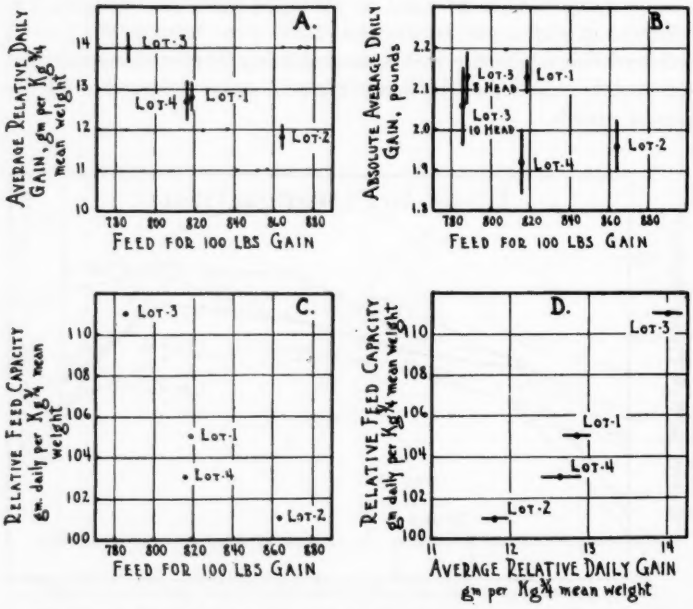

Figure 3. Graphs A and C illustrate the relation of average relative daily gain and of average relative daily feed capacity to the amount of feed required for 100 pounds' gain; Graph D, the relation of relative gain to relative feed capacity. Graph B shows the lack of correlation between average daily gain and feed required for 100 pounds' gain. The dots in A, B, and D represent the means, the lines the limits of the standard errors.

Lot 1 that had practically the same relative gain and relative feed capacity as lot 4, required the same amount of feed to produce 100 pounds of gain, although lot 4 gained about 0.2 pound less per steer per day. When gain and feed capacity are expresed in relative terms, both are highly correlated with economy of gain as indicated by graphs A, C, and D, figure 3. Graph B shows the lack of correlation between absolute gain (average daily gain) and economy of gain under the conditions of these tests.

The validity of these results rests largely upon whether or not the final degree of fatness and hence composition of gain was sufficiently similar. Both live and carcass grade averages were based upon a numerical system varying from 67 per cent for the low end of commercial grade and proceeding by 3-point intervals to 100 per cent at the top of the prime grade. Thus top good in our grading schedule is 82; low choice, 85; average choice 88; and so on. The slight discrepancy between live grade and carcass grade was largely due to placing greater emphasis on conformation than official carcass graders rather than to difference in estimating condition. Difference in average carcass grades between lots was not significant since all averaged in the low end of the choice grade. This equality of carcass grade together with the similarity of dressing percentage and degree of marbling observed in the "eye of beef" indicates that there was little difference in average degree of fatness between lots.

If the contention of Kleiber (1936) that relative feed capacity is a larger factor in economy of gain than variation in partial efficiency[3] of feed utilization is correct, then the close agreement between relative feed capacity and relative gain further indicates similarity in composition of gain and significance in differences in economy of gain. That is, if no difference existed in partial efficiency or in maintenance requirement per unit of metabolic size, then the relative rate of gain should be in direct proportion to relative feed intake providing composition of gain was equal.

Lots 3 and 4 were second-generation progeny of University-bred bulls, whereas lots 1 and 2 were first generation. The mothers of the latter groups were rather plain, somewhat upstanding, medium to good range cows. The earlier maturing qualities of lots 3 and 4 are reflected in their lighter weights at the time they reached the fatness required to grade low choice. The rapid fattening in the case of lot 3 could be attributed largely to its high relative feed intake and gain; that of lot 4 to being potentially smaller cattle. Several steers in the latter group attained choice grade at a weight of 750 pounds, and the difference between them and the average run of steers was comparable to that ordinarily found between steers and heifers of the same breeding. The sire in this case transmitted earliness of maturity that he himself exhibited and that also was shown by records on his full brothers. Height growth in the short period (45 days) for which records are available was less for lots 3 and 4 than for lots 1 and 2.

A summary of measurements and carcass data is presented in table 2 which shows some differences in conformation. Lot 2 averaged taller and longer bodies than any other lot. The height difference between lot 2

[3] Partial efficiency $= \frac{\text{gain}}{\text{total feed} - \text{maintenance feed}}$.

and lot 1 was not statistically significant, but the differences between either of these lots and lots 3 and 4 were significant. There was less difference in body length between lots than in height. Only the difference between lot 2 compared with 3 or 4 is significant. Lot 2 also had the longest

TABLE 2

Summary of Final Measurement, Grading, and Carcass Data
(Averages)

	Lot 1	Lot 2	Lot 3	Lot 4
Height at withers, cm.	115.0	117.2	109.2	111.4
Height at hooks, cm.	119.1	120.2	113.2	115.6
Heart girth, cm.	170.9	172.7	162.8	166.6
Paunch girth, cm.	200.3	199.6	187.1	180.2
Round measurement, cm.	100.8	100.2	99.9	97.0
Length, shoulder-pinbone, cm.	130.9	133.3	129.1	128.4
Head width, cm.	21.3	21.3	20.8	20.9
Head length, cm.	44.4	36.2	42.2	43.5
Ratio $\frac{\text{Round measurement}}{\text{Height}}$	87.7	85.5	91.6	87.1
Dimension weight index	24.0	22.5	24.0	23.7
Ratio $\frac{\text{Heart girth}}{\text{Paunch girth}}$	85.3	86.5	87.0	92.4
Ratio $\frac{\text{Head width}}{\text{Head length}}$	48.0	46.2	49.1	48.1
Eye-muscle width, cm.[1]	6.0 (6)	6.1 (5)	6.0 (7)	5.8 (5)
Eye-muscle length, cm.[1]	12.6 (6)	12.6 (5)	12.9 (7)	12.4 (5)
Ratio $\frac{\text{Eye-muscle width}}{\text{Eye-muscle length}}$	47.8	49.1	46.4	46.9
Eye-muscle area (length×width) per 100 pounds live weight[1]	0.87	0.88	0.99	0.91

[1] Eye-muscle measurements could not be obtained on all carcasses. The numbers in parentheses show the number obtained from each lot.

heads in relation to width, the difference between this and any other group being highly significant. Lot 3 showed the greatest muscle-skeletal index ($\frac{\text{round measurement}}{\text{height at withers}}$, (Gregory, 1933)). The difference between lot 3 and any other lot was highly significant. There was no significant difference in dimension-weight index (reciprocal of Yapp's (1924) index) between any of the lots. The correlations between these two indices of individual steers and the market grade was 0.44 ± 0.13 and 0.58 ± 0.11 respectively.

Lot 3 which had the highest muscle-skeletal index also had the largest eye-muscle area per 100 pounds body weight. The data are not complete and this interesting suggestion that the index may reflect differences in proportion of muscle to bone generally should be tested by dissection and weighing of bone and muscle.

These data have only indirect bearing upon the feed utilization test as such but are included because they form a part of the whole picture of records of performance and indicate the ways in which specific measurements have advantages when kept in addition to overall evaluation by grading in any long time study of hereditary and environmental variations.

Discussion

The results of these limited tests lend support to the thesis of Kleiber (1936) that body size is not fundamentally related to efficiency of production; that absolute rate of gain can be used as an index of efficiency only in comparing animals of similar (potential) size; and that relative gain and relative feed intake are in general sound indices of efficiency providing the composition of the gain is equal.

The technique used of approximately controlling composition of gain by slaughtering at equal degree of fatness offers opportunity to study efficiency of feed utilization of get of sire groups independently of potential body size and earliness of maturity variations. Selection for the latter factors should be decided upon on the basis of adaption to production methods, environment (including plane of nutrition), and of market requirement. Progress in breeding depends on isolating and clearly defining the numerous issues involved.

Judging from the results it appears possible, with the addition of suitable refinements, to distinguish differences between sire groups with reasonable accuracy. Some of the refinements indicated are (1) self feeding a mixed ration including cut roughage to permit free expression of appetite, (2) adequate determination of feed moisture content so that feed intake may be expressed in terms of dry matter or total digestible nutrients, (3) slaughter data including determination of total weight, bone weight and ether extract percentage in the meat of a standard 2-rib cut and weights of wholesale cuts from each carcass. These additions to the carcass data would permit verification of equality of finish and additional study of the true importance of conformation variations in terms of percentage yield of wholesale cuts and percentage of lean, fat and bone in the carcass. The carcass cuts suggested are whole round including rump, loin, prime rib, chuck, shin, and shoulder, and long plate. The carcass breakdown could be handled in cooperation with a packing company or other centralized jobbing establishments if experiment station facilities were inadequate.

Determination of the efficiency of an individual animal in a purebred herd appears to be more complicated and subject to error. Selection of the beginning and end point of the test period becomes more critical and difficult and slaughter data would be impracticable. The influence of milk production of the dam would be an important variable. Relative gain could be obtained readily by the regular weighing of animals maintained under uniform environmental conditions. The difficulty lies in selecting a period which not only represents corresponding sectors in the individual growth curves but also equal composition of gain.

Relative rate of gain or feed intake does not appear to be constant over extended periods. As shown in figures 1 and 2, both tended to rise during the early part of the period of decline as the animals approached market condition. The exception in relative gain of lot 2 was probably due to chance variation in fill which resulted in apparent low gain in period 3 and exaggerated gain in period 4. That this type of variation may be reduced by using shrunken weights (12 hours overnight without feed and water) is suggested by the data of Baker and Guilbert (1942) and by extensive data on range cattle (Wagnon, Guilbert, and Hart, unpublished).

Summary and Conclusions

Feed utilization tests were conducted on four gets of sire each consisting of 10 head of steer calves. The test was conducted on the basis of controlling the caloric value of the ration and feeding according to appetite. For controlling the energy content of the gain an attempt was made to feed to an equal degree of fatness. Under these conditions two lots having the same rate of gain differed significantly in economy of gain. Two groups having the same efficiency of gain differed significantly in rate of gain. Thus absolute rate of gain was not a satisfactory index of economy of gain in groups differing in potential mature size and in earliness of maturity. The relative rate of gain and relative feed capacity (gain and feed capacity per unit of metabolic body size, weight$^{3/4}$) were correlated highly with efficiency of feed utilization and with each other.

Isolation of some of the problems involved in selection for size and type on the one hand and economy of feed utilization on the other are discussed and some of the difficulties of obtaining an accurate index of efficiency of individual animals are mentioned.

The conclusion is reached that with suitable refinements the technique employed in these tests permits the determination of differences in efficiency of feed utilization between get of sire groups with reasonable accuracy.

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RATE OF CONCEPTION IN BEEF COWS PASTURE-BRED DURING A CONTROLLED BREEDING SEASON

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THE RATE at which beef cows are effectively bred in pasture matings not only influences the length of the calving season but also determines the rate at which the calves are born during the season. Many ranchers endeavor to have their calf crop come during certain months of the year and control the breeding season accordingly. In case the breeding season is controlled, the rancher would like to have some assurance of the number of cows that are pregnant before he removes the bulls.

Material

Records obtained in 12 successive years, from 1932 to 1943, on the purebred and crossbred herds of the Iberia Livestock Experiment Farm, Jeanerette, Louisiana, were used. During this period there was a total of 832 pasture matings. Of these, 563 resulted in normal births, 62 in abortions or premature births, and 207 infertile matings. Excluding the group of 62 abortions, this represents 73.1 percent crop of normal calves and 26.9 percent infertile or barren matings.

Table 1 shows the breeding history of the cows previous to the birth of normal calves. Of the 563 normal births 99 or 17.6 percent were from Bang-positive cows. It has been shown by Miller and Graves (1932) that

TABLE 1. BREEDING HISTORY OF 563 COWS THAT PRODUCED NORMAL CALVES AS THE RESULT OF PASTURE MATINGS

	Number	Percent
Heifers—2 years old	128	23
Cows—calved within 1 year of start of breeding season	331	59
Cows—1 year barren	45	8
Cows—2 or more years barren	10	2
Cows—Breeding history unknown*	25	4
Cows—aborted previous pregnancy	24	4
Total	563	100

* Purchased animals.

Bang's disease has no effect on the number of matings required for conception in Bang-positive and Bang-negative cows. Both groups are included in this study.

Of the 563 normal births, 90.1 percent were of crossbred Brahman × Angus or Africander × Angus calves and 9.9 percent were of purebred calves. No grouping on a genetic basis was made.

[1] Bureau of Animal Industry, Jeanerette, La.

During the 12 year period the length of the breeding season varied from 48 to 149 days with a weighted average of 95.3 days. The bulls were placed in the herds usually in March or April and removed in June or July. Only 1 bull was allotted to each herd which varied from 2 to 36 cows, with an average of 14.6 per breeding herd.

In this study the breeding herds of each year were grouped together and treated as one herd.

Procedure

In determining the rate at which cows are effectivenly bred in pasture matings it is necessary to employ indirect methods as the matings were not actually witnessed by an observer. For this purpose the generally accepted gestation period of 282 days and estrual cycle of 20 days were used. It is recognized that these are not constants but variables and some caution must be exercised in applying them in a study of this kind. They are, however, extensively used by the breeder in estimating the approximate date of birth when the date of conception is known and in estimating the return of estrum when the previous estrum or heat period is known.

This study employs the gestation period in reverse manner. Knowing the date of birth the date of conception is estimated by counting back 282 days. The 282nd day from the start of the breeding season is used as the basic date. From the rate at which normal live calves are born before and after the basic date is calculated the rate at which the cows conceived during the previous breeding season. Each 20th day in the previous breeding season, including the day the bulls were placed in the herds, marks the end of an estrual cycle during which every non-pregnant cow in the breeding herd normally came in heat and had an opportunity to become pregnant.

Results

Table 2 shows the rate at which pregnancy occurred during a breeding season extending over six estrual cycles as determined by the method above.

As expected there is an overlap into the period preceding the basic date. That is, for the first cycle, 21 calves or 3.7 percent, by actual count, were carried in-utero less than 282 days, and an equal number are assumed to have been carried in-utero more than 282 days. There is then an overlap of 21 calves into the second or succeeding period. The total overlap of the first cycle is then 42 calves. A comparable overlap must be assumed for each following cycle into the cycle preceding and succeeding it until the last cycle, which like the first, would have only 1 cycle overlapping into it. The overlap is in proportion to the number of non-pregnant cows remaining in the herd at the termination of each estrual cycle.

TABLE 2. UNCORRECTED RATE OF CONCEPTION DURING A BREEDING SEASON EXTENDING OVER SIX ESTRUAL CYCLES

Estrual cycle	Pregnancies	
	Number	Percent
Overlap	21	4
First	263	47
Second	161	29
Third	64	11
Fourth	31	5
Fifth	19	3
Sixth	4	1
Total	563	100

The number of conceptions that occurred in each cycle can be corrected for the overlapping. The calculation of the correction is based on the observed overlap of 21 or 3.7 percent. The procedure is simple. The number of cows effectively bred during the first cycle, corrected for the observed variation in length of gestation period is the uncorrected number, 263, less the overlap from the second cycle, 9.6, plus the overlap, 42, of the first cycle, or a total of 295. That is, 52 percent of the cows that eventually dropped normal calves were effectively bred during the first 20 days that the bulls were in the herds. The procedure is the same for the second and all subsequent cycles with the exception that there is an overlap from the preceding cycles as well as succeeding cycles that must be subtracted from the uncorrected number before adding the overlap of the given cycle into adjoining cycles.

Table 3 gives the number and percentage of normal pregnancies that occurred in each of the six estrual cycles corrected for overlapping due to variable gestation period.

TABLE 3. CORRECTED RATE OF CONCEPTION DURING A BREEDING SEASON EXTENDING OVER SIX ESTRUAL CYCLES FOR 100 PERCENT AND 73 PERCENT FERTILE HERDS

Estrual cycle	Number	Conceptions	
		100 percent fertile herd Per cent	73 percent fertile herd Per cent
First	295	52	38
Second	155	28	20
Third	61	11	8
Fourth	30	5	4
Fifth	19	3	2
Sixth	3	1	1
Total	563	100	73

Combining the group of 563 cows that gave birth to normal calves with the group of 207 cows that failed to conceive the percentage rate of conception for the herd is determined. This is shown in the last column of table 3.

Parturition and subsequent conception. With bulls remaining in the herds for as short a breeding season as 3 months in succeeding years there is some overlapping of the calving and breeding seasons. Eliminating all heifers and cows barren more than 1 year, Figure 1 shows the rate at 10-day intervals at which parturition occurred and the rate at which pregnancy followed with 331 cows that calved within 1 year of the start of the breeding season. Of

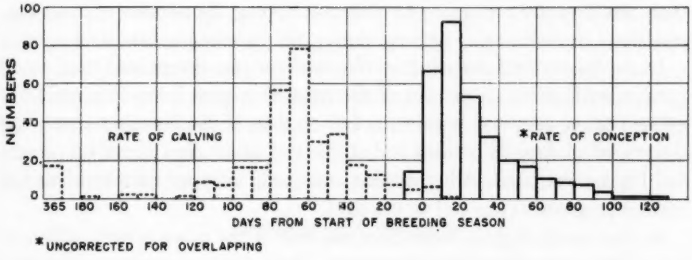

Figure 1. Rate of calving before start of the breeding season and rate of conception after start of the season for 331 cows that calved within 365 days from the start of the breeding season.

this group slightly more than one-half calved within 70 days of the start of the breeding season. Chapman and Casida (1937) give 70 days as the mean period between parturition and first subsequent estrus.

Elapsed heat periods per conception. Evidence from this study indicates there is little or no difference in the rate at which heifers and cows become pregnant when pasture-bred. Following the method used in table 3, the rate of conception of the 128 heifers was 52, 26, 11, 8, 2 and 1 percent for the first to the sixth cycle respectively. The observed overlap in the case of the heifers was 3.9 percent. The elapsed heat periods per conception were computed by multiplying the corrected frequency in each 20-day cycle by the order of the cycle and dividing by the total number of heifers. In the case of the heifers the result is 1.83 elapsed heat periods per conception and 1.80 for all other cows. The general average for all females, heifers and cows, that gave birth to normal live calves is 1.81. This, of course, is on the basis of one service during each heat period as is the general practice when cows are hand-bred.

Summary

An attempt has been made to determine the rate of conception with pasture-bred beef cows during a controlled breeding season that extended over a period equivalent to 6 normal estrual cycles. An indirect method of obtaining the basic data had to be employed as the matings were not actually witnessed by an observer. The 282nd day from the date the bulls were placed in the cow herds is taken as the basic date from which the rate of conception is determined by counting back 282 days from the date of birth of all normal calves. As some calves were born previous to the basic date there is an overlap the result of some calves being carried in-utero less than 282 days. A similar overlap is assumed for calves carried in-utero more than 282 days. By correcting for this overlapping the number of cows that conceived in each 20-day interval during the breeding season is computed.

Using the method described in this study it was determined that, when pasture-bred, about 52 percent of the cows that gave birth to normal live calves became pregnant within the first 20 days of the breeding season. At the end of 40 days 80 percent and at the end of 60 days about 90 percent had become pregnant. All cows that eventually dropped normal calves had become pregnant at the end of 120 days.

In this study slightly more than one-half of the cows calved within 70 days of the start of the breeding season. Only 8 or 1.4 percent calved after the season started.

There is no material difference in the rate of conception for heifers and cows. In the 100 per cent fertile herd an average of 1.81 heat periods elapsed for conception, 1.80 for cows and 1.83 for heifers.

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CLEAN-WOOL YIELDS IN SMALL SAMPLES FROM EIGHT BODY REGIONS AS RELATED TO WHOLE-FLEECE YIELDS IN FOUR BREEDS OF SHEEP

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THE AMOUNT of clean wool in the fleece is the most accurate measure of an animal's wool producing ability. In a breeding program for wool improvement when whole fleeces cannot be scoured, an estimate of the clean yield can be obtained by scouring small samples from each fleece. For example, Schott and coworkers (1942) found correlations between small side-sample yields and whole-fleece yields for Rambouillet, Targhee, Corriedale, and Columbia of .76, .71, .84, and .88, respectively. In an effort to find the most accurate sampling regions and to study the relationship of the small sample clean-wool yield from the different regions to that of the whole-fleece, the present study was extended to include 8 body regions in four breeds of sheep. Pohle and coworkers (1943) have conducted a similar study on 30 Rambouillet yearling ewes and reviewed the literature on this subject.

Material and Methods

Samples of wool were taken from eight body regions on 60 yearling ewes, 15 each from the Rambouillet, Targhee, Corriedale and Columbia breeds. These ewes were sampled the latter part of May, 1941, at the U. S. Sheep Experiment Station and Western Sheep Breeding Laboratory, Dubois, Idaho. The 60 ewes were selected at random from the total population within each breed. These sheep had been raised under typical Intermountain range conditions, grazing on the ranges the entire year except for about four months during the winter when they were in the feed-lot.

The samples were taken from the following 8 regions on each sheep: Withers (at top of withers); back (middle of back); rump (on back, just anterior to the dock); shoulder (over mid-point of scapula); side (at middle of side); hip (over point of hip bone); on thigh (even with underline); and on the belly (directly below the side sample and even with the underline where the belly wook begins but not directly at the mid-line of the belly).

Electric clippers (shearmasters) were used to remove the wool as close to the skin as possible from an area approximately 11 centimeters long and 5 centimeters wide. The wool was placed in moisture proof containers until time of weighing and scouring. Each sample contained from 25 to 35 grams of grease wool.

[1] U. S. Sheep Experiment Station and Western Sheep Breeding Laboratory, Dubois, Idaho.

The 480 samples were scoured in the Bureau of Animal Industry's animal fiber laboratory at Dubois, Idaho, by the method described by Hardy (1934). The entire fleeces (except the small samples) were scoured by the Agricultural Marketing Administration,[2] Washington, D. C., by the Method described by Buck (1940). The wool samples were dried in a conditioning oven at 212° F. for 6 hours to free the wool of moisture, and the clean yields obtained are subsequently referred to as bone-dry wool yields.

The statistical procedures used in the analysis of the data were chiefly those given by Snedecor (1940) for the analysis of variance and covariance. Since it seemed reasonable that the whole-fleece yields were less subject to error than the small-sample yields, the "true" relation between the two variables is most accurately represented by the regression of small-sample on whole-fleece yield (Eisenhart, 1939). Accordingly, whole-fleece clean yield is considered as the independent variable throughout this study.

Results

The mean yields from the 8 small-sample regions and from the whole-fleeces are given by breeds in table 1. The average of the 8 small-sample

TABLE 1. MEANS OF SMALL-SAMPLE AND WHOLE-FLEECE YIELDS*

Region	Breeds				Mean of 4 breeds
	Rambouillet	Targhee	Corriedale	Columbia	
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
Withers	37.3	38.9	39.4	38.2	38.4
Back	30.6	32.4	33.6	31.9	32.1
Rump	31.5	34.8	38.7	38.0	35.8
Shoulder	43.1	46.8	49.7	46.6	46.6
Side	37.2	41.6	45.6	42.4	41.7
Hip	42.5	46.8	50.5	48.9	47.2
Thigh	42.6	49.6	50.6	48.9	47.9
Belly	42.0	48.2	49.2	45.0	46.1
Mean of 8 regions	38.4	42.4	44.6	42.5	42.0
Mean of whole-fleeces	34.6	39.8	40.9	39.1	38.6

* Bone-dry determinations.

yields was greater than that of the whole-fleece yields for each breed. This was generally true for the 15 sheep within each breed, also. Using the unique sample method, a t value of 12.24 with 59 degrees of freedom indicated that the difference of 3.4 percent between average small-sample and whole-

[2] Acknowledgement is made to Warner M. Buck and George C. LeCompte of the Food Distribution Administration for the scouring of the entire fleeces.

fleece yield was highly significant. This indicates either that the lower yielding regions of the fleece produce the greater portion of the fleece (by weight), or that unsampled portions (such as tags, sweat locks, etc.) have a considerably lower yield than the average of the sampled regions.

Table 2 shows the analysis of variance for the whole-fleece and small-sample yields. Breed differences were highly significant for whole-fleece and small-sample yields. The small-sample analysis indicates that some regions

TABLE 2. ANALYSIS OF VARIANCE OF WHOLE-FLEECE AND SMALL-SAMPLE YIELDS

Source of variation	Whole-fleece yields			Small-sample yields		
	Degrees of freedom	Mean square	F	Degrees of freedom	Mean square	F
Total	59	18.05	—	479	63.8	—
Breeds	3	114.09	8.84*	3	835.3	5.74*
Regions	—	—	—	7	2132.6	84.63*
Breeds×region	—	—	—	21	25.2	—
Sheep within breeds	56	12.91	—	56	145.5	12.76
Sheep×regions within breeds	—	—	—	392	11.4	—

* Highly significant ($P < .01$).

are higher yielding than others. The gradient in yield for the different body regions for the 4 breeds was similar to that reported by Pohle and coworkers (1943) for Rambouillet fleeces. In the present case, the shoulder, hip, thigh and belly were the highest yielding regions while the back and rump were lowest in yield. Differences among sheep within a breed were highly significant also. A χ^2 test for the homogeneity of the variance within breeds did not differ more than was expected in a homogeneous population.

From the standpoint of developing an accurate equation for predicting whole-fleece yield from small-sample yield, we must determine whether the same a and b coefficients can be used for each breed and each region. Since whole-fleece yield was selected as the independent variable, a covariance analysis (Snedecor, 1940) was made separately for each of the eight regions with whole-fleece yield. The average regression coefficient (table 3, last column) was highly significant for each region. The mean square for the additional reduction due to the individual breed regressions was not significantly larger than that for deviations from the individual regressions in any of the 8 regions. In fact, the latter mean square was slightly greater than the former in 5 of 8 cases. Thus the average regression for a particular region, rather than the individual breed regression for that region, may be used in the regression equation.

It is of interest to note the extent to which variation in the 32 individual regressions in table 3 represents actual differences. Since the 8 regressions for each breed have one set of variates in common (whole fleece yields for 15 sheep), their sampling errors are less than those for independent regressions of similar size. An average difference of approximately 0.88 between the independent regressions is necessary at the 5 per cent level of significance. Among the 384 possible comparisons of independent regressions in table 3,

TABLE 3. REGRESSION COEFFICIENTS BY BODY REGIONS AND BREEDS

Region	Rambouillet	Targhee	Corriedale	Columbia	Average*
Withers	0.85	0.88	0.79	1.49	0.95
Back	0.87	1.02	0.57	0.92	0.85
Rump	0.86	0.74	0.63	1.50	0.87
Shoulder	1.10	0.65	1.41	1.03	1.02
Side	1.19	0.91	1.13	1.45	1.13
Hip	1.05	1.24	1.14	1.22	1.17
Thigh	1.11	0.75	1.23	0.92	0.99
Belly	1.20	0.95	1.36	0.56	1.05

* Calculated from the pooled sum of products and squares within breeds.

only 3 differ by as much as 0.88. Consequently, there is very little evidence that the true regressions for the 8 regions differ. The most significant observation is that there is a decided tendency for the lower yielding regions to have the smaller regressions. For example, the back, rump, and withers have the smallest mean yields as well as the smallest average regressions.

The *a* values (table 4) were calculated from the mean small-sample and whole-fleece yields (table 1) and the average regression coefficients for each region (table 3). Differences among the breed *a* values for each region were tested by calculating the mean square for breeds after adjusting for differences in whole-fleece yield. In 3 of the 8 cases, the mean square for adjusted yield was less than that for errors of estimate and was not significantly larger for any region. This indicates that the observed small-sample breed differences at any region can be explained by differences in the whole-fleece yields of the breeds. Consequently, the average *a* value (table 4, last column) for a particular region may be used for each of the breeds.

It is evident in table 4 that the *a* values for the 8 regions in the same breed differ much more among themselves than do *a* values for the same regions in different breeds. Although the differences in the *a* values for the 8 regions were not subjected to a direct test of significance, it is certain that they are statistically significant since the regional small-sample yields differed so widely.

TABLE 4. THE *a* VALUES FOR DIFFERENT BODY REGIONS AND BREEDS

Region	Rambouillet	Targhee	Corriedale	Columbia	Average
Withers	4.3	0.9	0.4	0.9	1.75
Back	1.2	−1.4	−1.2	−1.3	−0.59
Rump	1.3	0.1	3.0	2.9	2.17
Shoulder	7.9	6.3	8.0	6.8	7.19
Side	−1.9	−3.3	−0.6	−1.7	−1.94
Hip	2.2	0.4	2.8	3.3	2.02
Thigh	8.3	10.2	10.1	10.2	9.72
Belly	5.8	6.6	6.4	4.1	5.60

A covariance analysis was also carried out for the mean of the eight regional small-sample yields and the whole-fleece yield. The average regression was 1.00 and the average *a* value was 3.4. In support of conclusions previously reached, neither the adjusted breed means nor the individual breed regressions differed significantly.

The correlations between small-sample and whole-fleece yield are of interest chiefly because they serve to identify those regions in which the variations in small-sample yield are most similar to the variations in whole-fleece yield. The correlations are shown in table 5.

TABLE 5. THE CORRELATION COEFFICIENTS BETWEEN WHOLE-FLEECE YIELDS AND SMALL-SAMPLE YIELDS BY BREEDS

Region	Rambouillet	Targhee	Corriedale	Columbia	Average Correlation
Withers	.52	.62	.66	.57	.59
Back	.59	.70	.52	.46	.57
Rump	.61	.60	.43	.88	.63
Shoulder	.89	.55	.87	.64	.74
Side	.80	.54	.82	.84	.75
Hip	.85	.83	.83	.74	.81
Thigh	.89	.57	.82	.60	.72
Belly	.82	.78	.85	.43	.72

For differences between correlations involving two breeds, a difference of approximately .55 is required for significance (based on the average correlation and Fisher's Z test). For correlations involving the same breed, the difference required for significance is approximately .50. None of the correlations in table 5 differed by the amount required for significance. Hence, it cannot be said with any certainty that one region is more representative than another of variation in whole-fleece yield. However, the correlations involving the lower yielding regions (withers, back and rump) are lower than the others, as were the corresponding regressions.

So many factors may be important in influencing the relations between small-sample and whole-fleece yields that caution should be used in extending the interpretation of the above results too far. Many geographical, climatic, or biological factors may influence the *a* and *b* values.

From a practical standpoint our interest is chiefly in finding the most accurate regions for taking small samples and establishing accurate *a* and *b* values for use in the regression equation. It seems certain that the average regression of small-sample yield on whole-fleece yield should approach a theoretical coefficient of unity for thoroughly-sampled fleeces, provided the whole-fleece yields are accurately determined. This was found to be true in the present study. Schott and co-workers (1942) found an average regression of 1.08 for 174 side samples for these same breeds. Pohle and co-workers (1943) found a regression of the mean of the 8 regions on whole-fleece yield of 0.88 for 30 Rambouillet fleeces. None of these regressions differ significantly from each other or from a theoretical regression of unity. It appears fairly certain that the breed regressions are very similar. The regressions for individual regions are more variable than the breed regressions although the differences among them were not great enough to be statistically significant in the present study.

The *a* values were prevailingly positive because the small sample yields averaged higher than the whole-fleece yields. It is evident that the *a* values for the various regions are significantly different. The *a* values seem (in this study) to be similar at a given region for different breeds. Schott and co-workers (1942) found the *a* values for 174 side samples to be significantly different for these same breeds. The reasons for this disparity are not clear.

The withers, back and rump are the least desirable regions for taking small samples. The results of the present study and those of Pohle and co-workers (1943) agree in ranking these regions low in accuracy. These regions also gave the lowest clean yields. The differences in accuracy among the other 5 regions appear to be so small that the choice may be decided by whichever regions are the easiest to sample.

The most accurate *a* and *b* values in the regression equation appear to be those in the last column of tables 4 and 3, respectively, the choice of the particular coefficients depending upon the region sampled. For example, the predicted whole-fleece yield (x) would be obtained from a small-sample yield (y) at the hip (say) by solving the equation, $x = y - 2.02/1.17$.

With the usual method of predicting the "dependent" from an independent variate, the predicted values are less variable than actual values would be. It should be noted that the method of prediction employed in the present study has the opposite effect. In fact, the standard deviation of predicted values is $1/r_{xy}$ times that of the actual values. Accordingly, this method of

prediction will cause greater differences in predicted yields than would be found if whole-fleece yields could be determined by scouring entire fleeces.

Summary

Clean wool yields of small samples from 8 body regions were compared with the clean wool yields of the whole fleeces to determine the most accurate regions for sampling a fleece. Clean yields were obtained from 480 small samples and 60 whole fleeces from 15 yearling range ewes for each of the Rambouillet, Targhee, Corriedale and Columbia breeds at the U. S. Sheep Experiment Station and Western Sheep Breeding Laboratory, Dubois, Idaho.

The average bone-dry clean wool yields for all four breeds were highest from the shoulder, hip, thigh and belly with yields of 46.6, 47.2, 47.9 and 46.1 per cent of clean wool respectively. Lowest yields were found on the withers, back, rump, and side in most of the four breeds, with yields of 38.4, 32.1, 35.8 and 41.7 per cent of clean wool respectively. The average clean yield of the whole-fleece from the four breeds was 38.6 per cent.

The difference of 3.4 per cent between average small-sample and whole-fleece yield was highly significant. Breed differences were highly significant for whole-fleece and small-sample yields. Differences among sheep within each breed were also highly significant.

The *a* and *b* coefficients (with small-sample yield as the dependent variable) were similar for the four breeds but not for the eight regions. Thus the most accurate coefficients for predicting whole-fleece yields seem to be the *a* and *b* values for a particular region averaged for the four breeds.

The correlations involving the withers, back and rump are lower than the others, as were the corresponding regressions and are the least desirable regions for taking small samples. The differences in accuracy among the other five regions appear to be so small that the choice may be decided by whichever regions are easiest to sample.

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THE B VITAMIN REQUIREMENTS OF THE HORSE

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RELATIVELY little is known about the nutrition of the horse as compared with that of other farm animals. This is especially true with respect to their requirements for members of the B vitamins. In their natural habitat herbivorous animals such as the sheep and bovine may live on essentially the same feeds as the horse. It is now well established that the various B vitamins are not dietary essentials for ruminants, as they are produced by symbiotic action of microorganisms in the rumen. Conditions are much less favorable for microbic symbiosis in monogastric herbivora than in ruminants. It may be suspected then, that the dietary requirements of Equidae for the B vitamins differ from those of ruminants.

Evidence that the horse requires some B vitamins was reported almost two decades ago by Naito *et al.* (1925). These investigators fed horses a ration consisting of polished rice and rice straw supplemented with cod liver oil and minerals. The horses lost weight and developed symptoms that are characteristic of thiamin deficiency. Carlström and Hjärre (1939) reported that horses fed rations deficient in the B vitamins became emaciated and developed anorexia and incoordination of movements.

The present paper deals with investigations designed to determine if sources of the B vitamins are necessary for the normal growth of the horse, and to secure as much information as possible on the essentiality of individual members of the B vitamins.

Experimental

These investigations covered the major part of three years with two groups of six horses each. Registered Shetland ponies were used. They were about nine months of age at the beginning of the experiments. Shetlands have advantages over larger breeds, especially when the ingredients used in the rations are expensive. These animals are gentle and relatively easy to handle. Male animals were chosen as being more suitable than females for collection of urine. The detailed results of the urinary studies will be reported in separate communications. The ponies were housed in individual box stalls, and a record kept of the amount of feed consumed. At the beginning, the horses were weighed at two-week intervals, and after six weeks at

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intervals of one week. The ponies of the first group were exercised at irregular intervals in a small paddock devoid of feed. For the second group a muzzle was designed that prevented them from getting any food. They were exercised in a large paddock two or three times each week.

The composition of the rations is given in table 1. During the latter part of the experiment a new supply of beet pulp was secured, which was more bulky than the original lot. The horses refused appreciable amounts of it; therefore the per cent of beet pulp in the rations was reduced and a corresponding amount of corn added. Rations IV and VI were changed to contain 40 per cent of beet pulp and 49 percent of corn, while ration V was

TABLE 1. EXPERIMENTAL RATIONS*

Ration No.	I	II	IV	V	VI	VI-B
	percent	*percent*	*percent*	*percent*	*percent*	*percent*
Dried beet pulp	63	61	60	58	60	60
Corn, ground	26	26	29	25	29	29
Casein, purified	10	8	10	6	10	10
Brewers' yeast	—	5	—	10	—	—
Dicalcium phosphate	1	1	1	1	1	1
Riboflavin**	—	—	—	—	0.28	1.10
Niacin**	—	—	—	—	11.00	11.00
Calcium pantothenate**	—	—	—	—	1.39	1.39
Vitamin content of ration in mg. per 100 grams						
Riboflavin	0.07	0.18	0.08	0.33	0.36	1.18
Niacin	0.80	2.57	0.88	4.36	11.88	11.88
Pantothenic acid	0.17	0.43	0.18	0.68	1.57	1.57

* Sodium chloride was fed *ad libitum*. A concentrate of vitamins A and D was fed at weekly intervals.

** Milligrams of synthetic vitamin added per 100 grams of ration.

changed to contain 38 and 45 per cent of beet pulp and corn respectively. This did not make any material difference in the amount of riboflavin and pantothenic acid as shown for the rations in the table, but it did increase the amount of niacin. By the time this change was made, evidence had accumulated indicating that there was enough niacin in the basal rations (I and IV) to permit normal growth. Consequently it is considered that this change had no material bearing on the outcome and interpretation of the experiments.

Samples of various ingredients used in making the rations were collected at various times and assayed for niacin, riboflavin and pantothenic acid. The vitamin contents given in the table are the approximate averages based on the aggregate of all assays. Niacin was determined by the microbiological method described by Snell and Wright (1941), riboflavin by an improved microbiological method (Wegner *et al.*, 1942), and pantothenic acid by the microbiological method of Pennington *et al.* (1940), with modifications in

the basal medium and in the preparation of the sample to eliminate the effect of foreign growth stimulants.

Corn is a fairly good source of thiamin and pyridoxine and it is assumed that the rations would not be deficient in these vitamins. The validity of this is borne out by the satisfactory growth of the horses when synthetic vitamins other than thiamin and pyridoxine were fed. On the basis of the quantitative requirements of other mammalia for which riboflavin and pantothenic acid are dietary essentials, the basal rations I and IV were deficient in these vitamins. The amounts of niacin that these rations supplied would not meet the needs of either dog or man.

The first group of ponies was divided into two lots and fed the basal ration (I), and ration II, containing five per cent of yeast as a source of the B vitamins. After the animals had been on the experiment for about four weeks, they began to decline in weight. The loss in weight continued, so that at the end of eight weeks the need for making a change was apparent. The two ponies receiving ration II that contained yeast lost weight, but not as rapidly as those on the basal ration.

Two possibilities might account for the failure of the ponies to gain on these rations. The first was that the rations were lacking in one or more essential growth factors, probably of the B vitamins. The other was that the horse requires a ration with some roughage, and that the difficulties might be in the mechanical properties of the rations. With the view of securing information on the latter, the ponies that received ration I were fed rice straw *ad libitum*. Rice straw is generally considered a roughage of very poor quality.

Not all the growth curves are shown due to limited space. The performance of animals not presented is in accordance with those shown in figures 1 and 2. With the addition of the rice straw to ration I the decline in weight ceased and was followed by a gain. During 15 weeks that rice straw was fed, the animals made satisfactory gains. With Docmar the feeding of rice straw was discontinued; a decline in weight followed. Subsequently the analysis of rice straw for riboflavin and pantothenic acid showed that it was a fairly good source of these vitamins. This is perhaps not surprising as rice bran is a good source of several of the B vitamins. However, the feeding of rice straw was with the idea that it would furnish bulk and little else of nutritive value. After the riboflavin and pantothenic adid content of the rice straw had been determined, it seemed that the benefits from the rice straw might be due to vitamins it furnished rather than to the bulk it added. The satisfactory growth of the ponies fed the extra yeast supports this hypothesis.

The two ponies on ration II were fed 35 grams of brewers' yeast daily in addition to the five percent in the ration. This, together with the yeast in

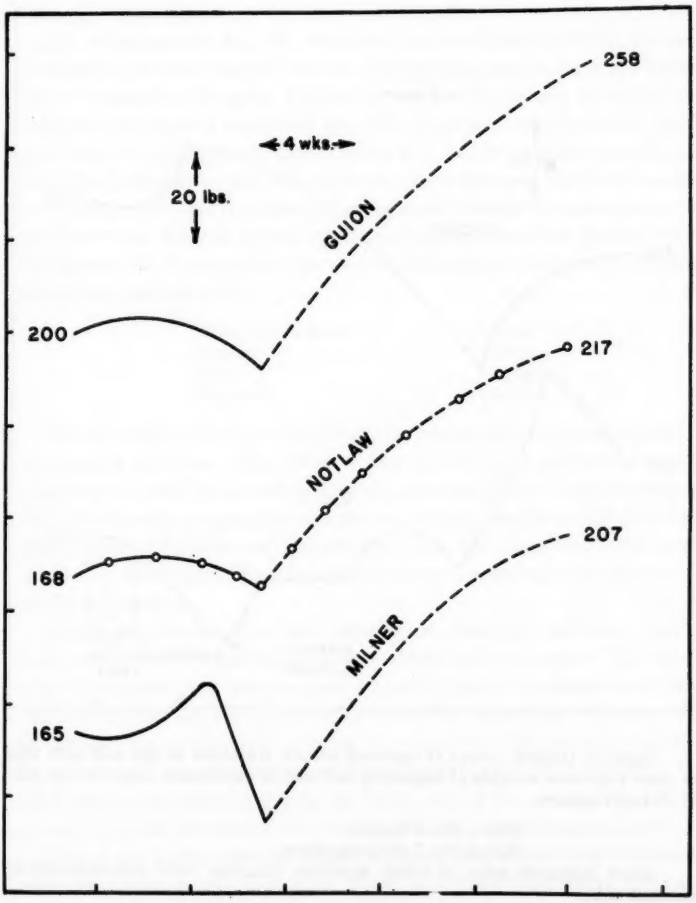

Figure 1. Growth curves of Shetland ponies. Numbers on left and right side of chart represent weights at beginning and end of experiment respectively. Key to dietary regimen:

———— **Ration No. I (basal).**
---------- **Ration No. I plus rice straw.**
○—○—○ **Ration No. II (containing 5% of brewers' yeast).**
○---○---○ **Ration No. II plus 35 grams of brewers' yeast daily.**

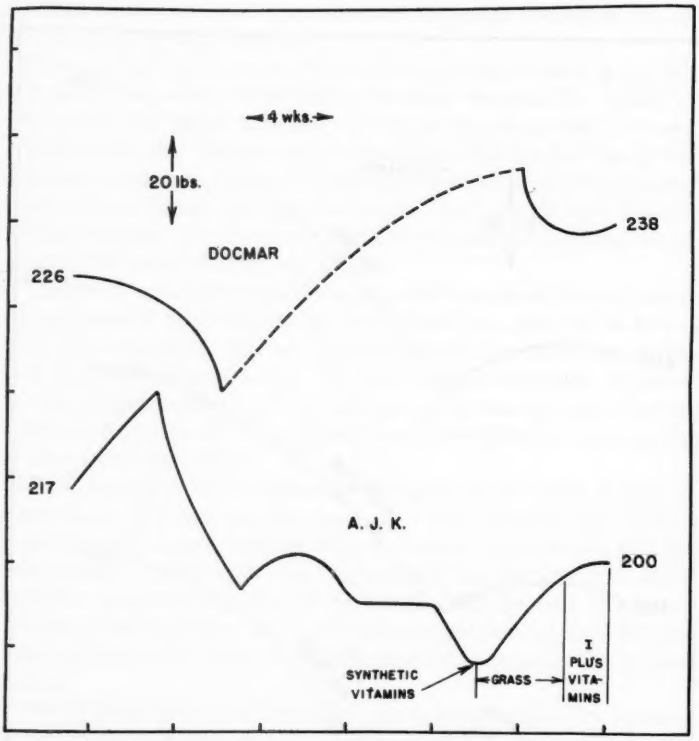

Figure 2. Growth curves of Shetland ponies. Numbers on left and right side of chart represent weights at beginning and end of experiment respectively. Key to dietary regimen:

———— Ration No. I (basal).
– – – – – – – – Ration No. I plus rice straw.
Arrow indicates point at which synthetic vitamins were administered by stomach tube.

the ration, would be equivalent to approximately 10 per cent of yeast in the ration, with some variation depending on the amount of feed consumed. With the feeding of the extra yeast, growth was resumed and continued at a satisfactory rate. The growth curve for Notlaw is shown in figure 1. The fact that the ponies made satisfactory gains on a ration devoid of a roughage is of interest as it is a prevalent belief among practical horsemen that a certain amount of roughage is essential for the horse. Perhaps the roughage

furnishes some essential factor or factors that are lacking in the concentrates normally fed to horses.

One of the ponies, A. J. K., was continued on ration I without any supplement for four and one-half months. During this time he showed a continual but somewhat irregular decline in weight. He became emaciated and weak and developed a staggering gait. The latter may have been from weakness rather than a symptom characteristic of a deficiency of any specific vitamin. The decline in weight was accompanied by anorexia. He finally reached a moribund state, and it appeared that he would not survive unless we could get him to eat. He was turned out on good green grass, but showed no inclination to eat. Twenty-four hours later the following vitamins were administered by stomach tube:

Calcium pantothenate	100 mg.
Thiamin	50 mg.
Niacin	500 mg.
Riboflavin	100 mg.

The following morning it was noted that his appetite had returned and he was grazing the grass. After three or four days on grass he showed marked improvement, and by the end of a week a new coat of hair began to come in. After four weeks on grass he was put on ration I, supplemented with synthetic niacin, riboflavin, and pantothenic acid. The experiment was terminated four weeks later. The time on this ration was too short to give any essential information.

Second Experiment. The first experiment definitely indicated that at least some of the B vitamins are dietary essentials for the horse. The experiment the second year was designed to secure further confirmation of this, and information on the quantitative needs for individual vitamins. The second experiment covered a period of 17 months. The growth curves in figure 3 extend only to the time when the ponies approached maturity. The chief information secured during the latter part of the period concerns the urinary excretion of some of the vitamins and the amounts in the blood.

Two of the ponies were fed ration V, containing 10 per cent of brewers' yeast for approximately 10 months. They both made satisfactory gains and were in good condition throughout the entire period. The growth of Rondo, which was similar to that made by Cleburne, the other pony, is depicted in figure 3. After 10 months on ration V these ponies were changed to ration IV. On this ration they failed to make further gains and gradually lost weight. The loss in weight, however, was not as great or rapid as it was at the time when the ponies were younger.

Bastrop was started on ration IV, which contained no extra source of any of the B vitamins. He lost weight rapidly on this ration, and by the end

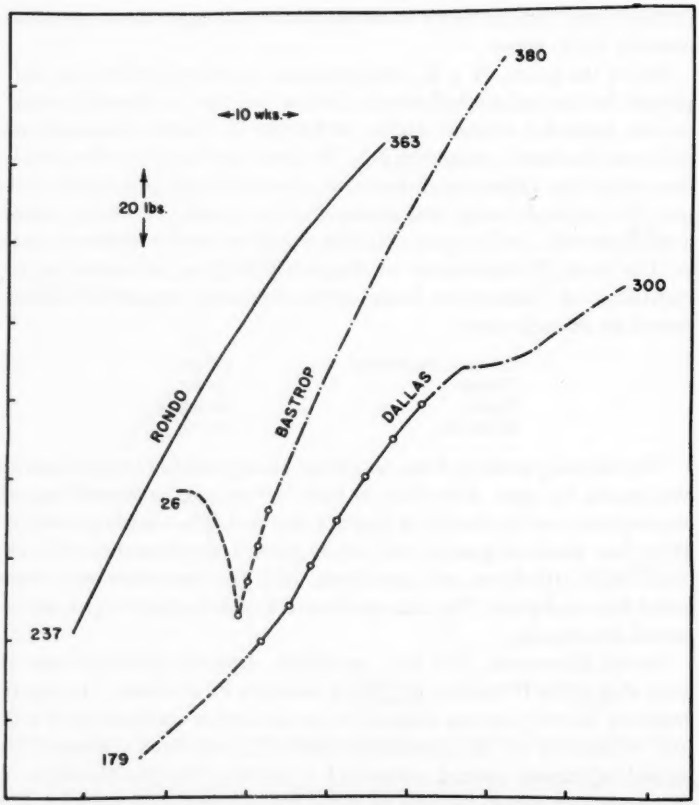

Figure 3. Growth curves of Shetland ponies. Numbers on left and right side of chart represent weights at beginning and end of experiment respectively. Key to dietary regimen:

---------- **Ration No. IV (basal).**
———— **Ration No. V (containing 10% brewers' yeast).**
O---O---O **Ration No. IV plus grass.**
—·—·—·— **Ration No. VI (containing synthetic vitamins).**
O—O—O **Ration No. VI-B (containing synthetic vitamins).**

of eight weeks it appeared imminent that some change must be made in his dietary regimen, so he was turned out on grass. He had not reached the moribund state that A. J. K. had the previous year. Soon after he was turned out on grass, he started to show improvement. After he had regained his

original weight, he was taken off the grass and fed ration VI, containing synthetic niacin, riboflavin, and calcium pantothenate. He was fed this ration for approximately seven and one-half months. During this time he made satisfactory gains, which were comparable to those made by the ponies fed ration V. One of the ponies, Dallas, was fed ration VI from the beginning of the experiment. In contrast to Bastrop, Dallas made satisfactory gains from the very beginning. During the course of the experiment the amount of synthetic riboflavin was increased, so that the total content in the ration (VI-B) was 1.18 mg. per 100 grams. This was done principally for the urinary studies and has no particular bearing on the growth performance of the animals. Shortly after Dallas was changed back to ration VI, he developed diarrhea. This probably accounts for the irregular rate of growth which occurred at about this time. During both the first and second experiment four or five of the ponies developed diarrhea, and with three of the animals it became so severe that it was necessary to take them off the experimental ration. It was not possible to relate the incidence of the diarrhea to the adequacy of the diet in the B vitamins or to other specific properties of the ration.

Studies on the urinary excretion of niacin indicate that either the horse does not require this vitamin or that there was an adequate amount in the basal ration. During the latter part of the experiment, synthetic niacin was omitted from rations VI and VI-B. This change, as previously mentioned, had no apparent effect on the growth of the ponies or on the course of the experiment.

From the figures it appears that riboflavin and pantothenic acid are both dietary essentials for the horse. Since none of the animals were fed a ration supplemented with riboflavin and pantothenic acid separately, the data on growth do not conclusively show that both of these vitamins are dietary essentials for Equidae. Studies on the urinary excretion of these vitamins as affected by various dietary regimens definitely indicate that both of them are dietary essentials for the horse (authors' unpublished data). On the basis of urinary studies, Pearson *et al.* (1944) reported that a daily intake of 44 mg. of riboflavin per kilogram of body weight satisfies the requirements of the horse for this vitamin. This is approximately the amount of riboflavin furnished to the ponies by rations V and VI. Using growth as a criterion of the requirements, an intake of 44 mg. of riboflavin per kilogram of body weight per day satisfied the requirements of the horse for this vitamin under the conditions of the experiment. Sebrell *et al.* (1941) reported that the daily requirements of humans for riboflavin is between 35 and 60 mg. per kilogram of body weight. Thus it appears that the requirements of the horse and man for riboflavin are of the same order.

Summary

Investigations were made using Shetland ponies to determine if a source of the B vitamins is required for Equidae. Rations made up of beet pulp, corn, purified casein, salts, and vitamins A and D failed to support growth. When 10 per cent of yeast was added to such a ration, horses made satisfactory gains. Five per cent of yeast was not adequate to support growth. Rice straw was found to be a fairly good source of riboflavin and pantothenic acid, and its addition to the ration promoted satisfactory gains.

Suppelementing the basal ration with synthetic riboflavin and pantothenic acid resulted in essentially as good growth as including 10 per cent of yeast in the ration. A ration containing 0.35 mg. of riboflavin per 100 grams was adequate for the normal growth of the horses under the experimental conditions described. This is equivalent to an intake of approximately 44 mg. of riboflavin per kilogram of body weight per day.

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SOME FACTORS AFFECTING THE BLOOD PHOSPHORUS LEVEL OF RANGE EWES[1]

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DETERMINATIONS of normal levels of inorganic blood phosphorus of sheep have been made in widely scattered regions of the world. Watson (1933b) found mean concentrations varying from 4.1 to 4.7 mg. inorganic phosphorus per 100 ml. of blood with individual concentrations varying from 2.8 to 5.9 mg. These data were based on 80 observations of 40 wethers on natural pasture in the Adelaide district of South Australia. Norris and Chamberlin (1929) found concentrations from 4.1 to 7.5 mg., mean 5.6 mg. from 32 sheep at the Melbourne abattoirs. Rossouw (1930) reported concentrations of 4.5 to 6.8 mg., mean 5.1 mg. for 10 sheep on ordinary rations at Onderstepoort, South Africa. In Scotland, Auchinachie and Fraser (1932) found values from 4.4 to 6.4 mg. with an average of 5.1 mg. from 26 wether hoggets on pasture. Boughton (1940) has made phosphorus determinations on various groups of sheep over a 3-year period in the Edwards Plateau of Texas. He found no signs of phosphorus deficiency, and reports that seasonal variations in blood phosphorus could be closely correlated with seasonal changes in range vegetation. Boughton further states[4] that blood phosphorus was highest in the spring and early summer, averaging from 4 to 5 mg. and was lowest during the late summer, fall and winter when the pastures were dry, averaging as low as 3 mg.

Other workers have studied the effects of phosphorus intake on blood phosphorus in sheep. Dutoit *et al.* (1930) concluded that the concentration of inorganic phosphorus in the blood was a reflection of the amount of phosphorus in the diet and was remarkably constant as long as feeding conditions were unchanged. These results were confirmed by Malan (1930), Bekker (1932), Dutoit *et al.* (1932), Martin and Peirce (1934), and Dutoit *et al.* (1935). Beeson *et al.* (1937) working with growing and fattening lambs also found a definite relationship between phosphorus in the feed and blood phosphorus.

While it is generally recognized that sheep produced under range conditions may be subjected to feed conditions which are not adequate in phosphorus, no detailed reports have been made on the levels of blood phosphorus

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for range sheep in the United States. Bekker and Rossouw (1930) in the Bredasdorp district of South Africa, reported that sheep under range conditions did not receive enough phosphorus for physiological requirements, and hence suffer from aphosphorosis. They found this condition was associated with low blood phosphorus levels. According to the review of literature on aphosphorosis in ruminants by Theiler and Green (1932), sheep display symptoms similar to those of cattle when fed on diets inadequate in phosphorus. Such symptoms may include a depraved appetite, weakness, stiffness of the joints and an unthrifty condition. Several unpublished reports of cases of aphosphorosis have been diagnosed among ewes under range conditions in Idaho. Usually these cases result from prolonged feeding on dry fall range, followed by wintering on alfalfa hay that is low in phosphorus (0.15 per cent or less phosphorus).

The question has been raised as to whether range forage provides adequate phosphorus for optimum growth and reproduction of range sheep, particularly in the fall and winter months. It is also questionable if pregnant ewes fed on hay deficient or low in phosphorus receive sufficient phosphorus for good reproduction. Although pronounced symptoms of phosphorus deficiency in range sheep are not common, there is a possibility that deficiencies may be detrimental though no symptoms are manifested.

The object of this study is to determine the blood phosphorus level of range sheep through the year and its variation in relation to seasonal changes in types of feed.

Experimental Procedure

Blood samples were collected from a group of about 40 Columbia ewes at definite seasonal intervals for a period of four years. The Columbia ewes were a part of the breeding flock of the United States Sheep Experiment Station, Dubois, Idaho. Any animals which died or were culled were replaced, usually with younger ewes. The ewes were kept under intermountain range conditions which involved the use of typical spring, summer, fall, and winter range areas. They were wintered on alfalfa hay and fed a supplement of grain after lambing.

In general, blood samples were taken at the following seasonal intervals: —When ewes came off the fall range, off the winter range, during the winter feed lot period, during the lambing period, off the spring range, and off the summer range.

Blood samples were collected from the jugular vein of the ewes, centrifuged and the blood plasma shipped to the University of Idaho, Moscow, for analysis. Inorganic blood phosphorus was determined colorimetrically by a slight modification of the Fiske and Subbarow (1925) method and is reported as mg. for 100 ml. of blood plasma.

Results and Discussion

The results are summarized in table 1 and figure 1. Individual variations in blood phosphorus level were noted. Seasonal trends, however, were fairly definite and variations between seasons were highly significant. Blood phosphorus levels were fairly low in September and November, followed by an increase in December and January. The highest average blood phosphorus content was found on the winter range in the latter part of January followed

TABLE 1. SEASONAL VARIATIONS IN BLOOD PHOSPHORUS LEVELS OF RANGE EWES

Type of range	Date	1938–39		1939–40		1940–41		1941–42		1938–42	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
		mg.%[1]	mg.%	mg.%	mg.%	mg.%	mg.%	mg.%	mg.%	mg.%	mg.%
Fall range	Nov. 16	3.2–6.0	4.93	2.6–5.5	4.10						4.52
	Dec. 14–18			3.4–6.2	5.18	4.0–8.0	5.11	4.0–6.7	5.20		5.16
Winter range	Jan. 6					4.2–7.3	5.30				5.30
	Jan. 17–24	4.1–6.5	5.14	4.6–8.2	6.08	4.1–9.9	6.16[2]	4.3–8.5	5.99[2]		5.85
Alfalfa hay in feed lot	Feb. 19	4.0–6.6	5.08					3.0–7.3	4.83		4.96
	Mar. 27–Apr. 3			3.3–5.2	4.26			3.6–8.0	4.88[2]		4.56
	Apr. 19–21			2.3–5.3	3.81[2]	2.5–8.3	4.31[2]	3.1–7.3	5.08[2]		4.39
Spring range	June 10–17			3.8–7.2	5.39	3.2–8.2	5.47	3.9–8.9	5.71		5.53
Summer range	Sept. 3–13			3.1–5.9	4.57	3.2–7.1	4.60				4.59

[1] mg. inorganic phosphorus per 100 ml. blood plasma.
[2] after supplemental feeding of cottonseed cake or oats.

by a decrease in the feed lot to the lowest level at lambing time. A high blood phosphorus content was found again on the spring range in June. Significant variations between years were found for the winter range, at the end of the winter feeding periods, at lambing time, and in November on the fall range. These appear to be the seasons when the factors affecting blood phosphorus are most variable.

Supplemental feeding of cottonseed cake or oats in the winter appeared to increase the blood phosphorus. In the years when ⅓ pound of cottonseed cake was fed for a 3-week period on the winter range, the average inorganic phosphorus content of the blood was 6.08 mg. per 100 ml. plasma as compared with 5.60 mg. when no supplement was fed. When ½ pound of oats per head per day was fed on the winter feed lot the phosphorus content of the blood averaged 4.88 mg. as compared with 4.25 mg. when no oats were fed.

Table 2 shows the analysis of variance on data from 11 ewes from which

blood phosphorus determinations had been made at each of 4 seasons (fall range in December, winter range, lambing, and spring range) for 4 years. Highly significant variations were found among seasons but not among ewes or years. Highly significant interactions were found in each case indicating

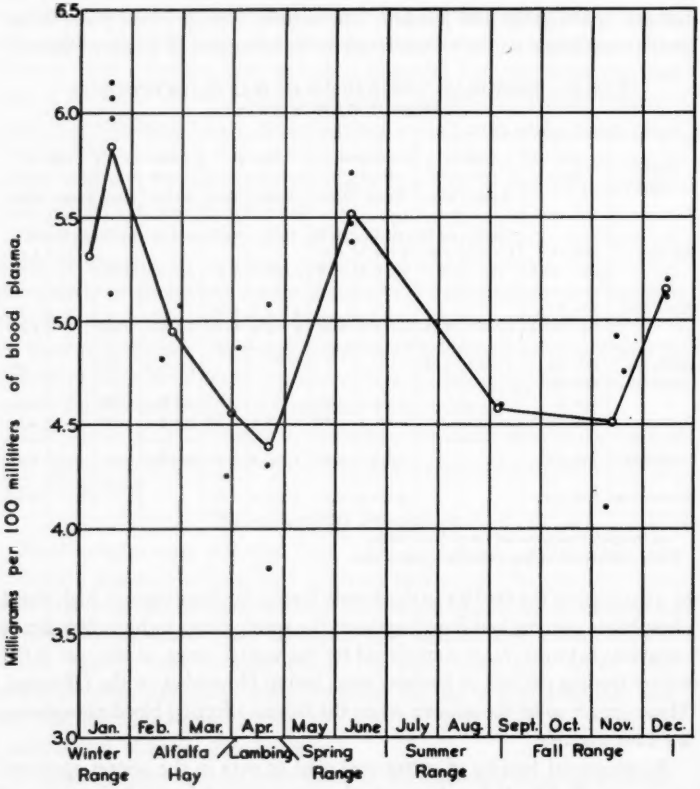

Figure 1. Blood phosphorus content by seasons. The black dots represent yearly averages while the small circles show the average for all years.

that the rank of ewes, in different seasons or years and of seasons in different years, vary significantly. Interaction of ewes with seasons or years might be brought about by differences in reproduction of these ewes. Interactions between seasons and years might have been due to annual variation in range conditions, or to supplemental feeding.

Blood samples were collected at lambing time when about half of the ewes had lambed. Blood phosphorus levels were higher for ewes that had not lambed (4.53 mg.) than for ewes that had (4.06 mg.). Ewes which had recently dropped single lambs had an average blood phosphorus content of 4.38 mg. as compared with 3.60 mg. for ewes which had recently dropped twin lambs. Dry ewes had an average blood phosphorus content of 5.84 mg. which was much higher than for ewes which had lambed or were going to lamb. Apparently the demands for phosphorus are so great just prior to and after parturition that there is a natural lowering of the blood phosphorus even though the phosphorus intake is ample for maintenance.

TABLE 2. ANALYSIS OF VARIANCE FOR INORGANIC BLOOD PHOSPHOROUS CONTENT OF RANGE SHEEP

Source of variance	Degrees of freedom	Mean square	F′
Total	131	1.18	
Seasons	3	16.15	8.54*
Years	2	.98	.52
Ewes	10	2.79	1.48
Seasons×years	6	1.57	31.40*
Seasons×ewes	30	.89	17.80*
Years×ewes	20	1.89	37.80*
Seasons×years×ewes	60	.05	

* $P < 0.01$, highly significant.

Blood samples taken in the middle of June, toward the end of grazing on the spring range, were obtained after lambing and shearing had been completed. At this time ewes suckling 2 lambs had an average blood phosphorus content of 5.22 mg. ewes suckling 1 lamb, 5.58 mg., and dry ewes, 5.81 mg.

The blood phosphorus content at the end of breeding in the middle of December was found to be definitely higher (5.18 mg.) for those ewes which later had single lambs than for those ewes which later had twin lambs (4.85 mg.). This difference was apparent within age groups. Terrill and Stoehr (1939) have found with range ewes under conditions nearly identical with those of this study that ewes which gain in weight during breeding are more apt to have twin lambs than those which lose weight. Therefore the relation of gain or loss in weight during breeding with blood phosphorus was investigated. Two-year-old ewes were excluded from this comparison because practically all of them have single lambs. It was found that ewes which lost weight during breeding had a slightly higher blood phosphorus content than those which gained in weight during breeding. It is reasonable to conclude that the relation between blood phosphorus content at breeding time and

the lambing rate was due more to the effect of gain or loss in weight or factors contributing to gain or loss in weight than to any effect of blood phosphorus on the ovulation rate.

The relation of gain or loss in weight to blood phosphorus partially explains the high blood phosphorus contents obtained on the winter range where phosphorus intake naturally would be low. Ewes generally lose weight on the winter range and therefore the level of nutrition is probably below maintenance requirements. Watson (1933a) has observed that there is a rapid increase in blood phosphorus of sheep during starvation which is attributed to increased tissue breakdown. It seems reasonable that rations below the maintenance level might have the same effect although to a lesser degree. Marston (1935) warns that diagnosis of aphosphorosis by low blood phosphate levels may be misleading as the level of phosphate in the blood is increased if the animal is either out of energy balance or not satisfying its protein requirements. There is an apparent parallel between the changes in blood phosphorus levels and observed gain or loss in condition or weight throughout the year. Blood phosphorus was highest on the winter range where the ewes usually lose weight and it decreased during the winter feeding of alfalfa hay when they were gaining in weight. Low blood phosphorus levels were found around lambing time when the expected demands for reproduction would be high. In general, ewes with low reproductive rates had low blood phosphorus levels. Blood phosphorus levels were again high on the spring range where the ewes were losing weight while suckling lamps. The blood phosphorus decreased in the late summer and early fall after the lambs had been weaned and the ewes were gaining in weight.

There is an indication that blood phosphorus tended to decrease with age. Table 3 was made up from all ewes bled from 1938 to 1941 from which a determination had been made from each bleeding within the year. Norris and Chamberlin (1929) found an average inorganic blood phosphorus of 6.30 mg. for 26 lambs as compared with 5.60 mg. for mature sheep. Beeson *et al.* (1937) found the average inorganic blood phosphorus of lambs at an average weight of 71 pounds was about 5.18 mg. per 100 cc. of plasma.

No definite evidence of phosphorus deficiency was found at any time during the year, except low blood phosphorus levels. Blood phosphorus levels of 3.50 mg. or below which might be considered as deficient were found at all seasons except on the winter range. The percentages of ewes having blood phosphorus levels of 3.5 mg. or below for the various seasons were 5.3 for the fall range, 2.5 for the feed lot, 20.0 at lambing, 2.7 for the spring range, and 10.0 for the summer range. It was expected that fall or winter feeds would be most apt to be deficient. The alfalfa hay fed during the winter feed lot varied in phosphorus content from 0.12 to 0.18 per cent.

TABLE 3. VARIATION IN BLOOD PHOSPHORUS CONTENT WITH AGE

Age of ewe in years	No. of ewes	Mg. inorganic phosphorus per 100 ml. blood plasma
2	27	5.24
3	28	5.26
4	23	5.16
5	15	4.67
6	14	4.88
7	9	5.09
8	2	4.14

Work by Beeson *et al.* (1939) has shown that rations containing 0.14 per cent or less phosphorus on the air-dry basis are inadequate in phosphorus and further that some of the range plants which are more commonly eaten by sheep were below this level in the fall and winter. It is possible that the relation between loss in weight and blood phosphorus may partly explain the failure of deficiency symptoms to appear on the winter range.

Summary

Data are presented from a four-year study on the seasonal variation in the blood phosphorus level of range ewes. Blood samples were collected from a group of about 40 Columbia ewes at 3 to 7 different times during the year.

Seasonal trends in blood phosphorus level were fairly definite and variations between seasons were highly significant. Highest blood phosphorus levels were found on the winter and spring ranges, while lowest levels were found at lambing time, in the late summer and fall, and on the winter feed lot. Supplemental feeding of cottonseed cake or oats on the winter range or feed lot increased the phosphorus content of the blood.

Blood phosphorus was lower for ewes that had lambed than for ewes that had not yet lambed. Dry ewes had higher blood phosphorus than ewes which were pregnant or were suckling lambs. Ewes with one lamb had higher blood phosphorus than ewes with two lambs.

A relationship was found between gain or loss in body weight and blood phosphorus. Ewes which were losing weight tended to have higher blood phosphorus.

Blood phosphorus tended to decrease with age.

No definite evidence of phosphorus deficiency was found except low blood phosphorus levels. The percentage of ewes having blood phosphorus values of 3.50 mg. or below for the various seasons were 5.30 for the fall range, 2.50 for the feed lot, 20.0 at lambing, 2.7 for the spring range and 10.0 for the summer range.

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THE FAILURE OF ASCORBIC ACID TO AUGMENT EQUINE GONADOTROPIN IN THE RAT[1]

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DURING the past decade evidence has been accumulating concerning the role of ascorbic acid in the regulation of the normal reproductive processes and the endocrine relationships of vitamin C utilization. Biskind and Glick (1936) reported the corpus luteum of pregnancy to be an exceptionally potent source of ascorbic acid. Israel and Meranze (1941) reported that vitamin C had a progesterone-like effect on the endometrium of the ovariectomized mouse, rat and rabbit. Pratt (1943), however, has recently reinvestigated this problem and concluded that there was no evidence of a progesterone-like effect in a series of rabbits in which ascorbic acid was injected both subcutaneously and directly into the uterus.

Erb and Andrews (1942) found in sexually mature male and female cattle the subcutaneous injection of equine gonadotropin resulted in a decrease in blood plasma ascorbic acid up to 67 per cent within 24 hours and that a similar response could be secured with the castrate male bovine.

Giedosz as reported by Di Cio and Schteingart (1942) injected adult female rabbits with gonadotropin and with the gonadotropic hormone in conjunction with ascorbic acid. The ovaries of the does injected with both ascorbic acid and gonadotropin were larger than those of the animals receiving only the gonadotropic hormone. Di Cio and Schteingart (1942) were unable to verify Giedosz' findings in the rabbit but reported that in the rat gonad size was almost doubled by the simultaneous injection of ascorbic acid and the gonadotropic hormone. These results were obtained with both male and female rats of from 2 to 4 months of age when injected for 20 to 30 days with 25 R.U. of gonadotropin and 50 mg. of ascorbic acid daily. No augmentation was observed in rats treated for 3-day periods and the injection of adult rats had no observable effects.

Andrews and Erb (1943) treated chicks from 1 to 29 days of age simultaneously with 10 R.U. of equine gonadotropin and from 25 to 75 mg. of ascorbic acid daily for periods of 5 to 15 days. They reported that ascorbic acid either alone or in combination with pregnant mare serum did not influence the testis weight of the White Leghorn chick under the conditions used.

Because of the inability of workers in our laboratory to demonstrate any augmentation of equine gonadotropin with ascorbic acid in the chick, an attempt was made to substantiate the findings of other workers with rats.

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Materials and Methods

Because of the general use of 21- to 24-day old rats for the assay of gonadotropins it was decided to compare animals of this age with those of older groups such as were utilized by Di Cio and Schteingart (1942) (2 to 4 months). In the first experiment 52 male and 49 female rats of the Wistar strain were observed. One group of each sex was injected subcutaneously with 25 R.U. of gonadotropic hormone daily for 4 days beginning on the 24th day of age. A second group of each sex received 25 R.U. of equine gonadotropin plus 50 mg. of ascorbic acid, and uninjected controls were maintained in the third group. The rats were autopsied on the day following the last injection and the testes or ovaries and uterus were removed, blotted with filter paper to remove excess fluid and weighed. In the second experiment 53 male and 45 female rats were studied. The injection groups were the same as previously described except that injections were begun when the rats reached 70 days of age and were continued for 20 days.

The gonadotropic hormone used was equine pregnancy serum[2] standardized to contain 50 R.U. per cc. Crystalline ascorbic acid[3] was made up immediately before use in 0.5 cc. of 0.1 N potassium hydroxide per each 50 mg. Ascorbic acid made up in distilled water caused excessive necrosis of the subcutaneous tissues and this was partially overcome by the reduction of the acidity of the solution.

Results

As shown in tables 1 and 2 the injection of 50 mg. of ascorbic acid daily for 4 days did not augment the gonadotropic hormone in either male or female rats. When rats 70 days of age were injected with ascorbic acid and equine

TABLE 1. EFFECT OF EQUINE GONADOTROPIN ALONE AND IN COMBINATION WITH ASCORBIC ACID ON TESTES OF 24 DAY-OLD RATS

Treatment	Number of Rats	Average Body Weight at Autopsy	Average Weight of Testes
		gm.	gm.
Ascorbic acid and gonadotropic hormone	22	50.0	0.462
Gonadotropic hormone	17	51.9	0.477
Uninjected controls	13	50.8	0.298

[2] The equine gonadotropin (Gonadin) was furnished by Donald H. Wonder, Director of the Endocrine Division, Berkeley, California.

[3] The ascorbic acid was supplied by Merck and Co., Rahway, N. J.

TABLE 2. EFFECT OF EQUINE GONADOTROPIN ALONE AND IN COMBINATION WITH ASCORBIC ACID ON GENITALIA OF 24 DAY-OLD FEMALE RATS

Treatment	Number of Rats	Average Body Weight at Autopsy	Average Weight of Ovaries	Average Weight of Uterus
		gm.	gm.	gm.
Ascorbic acid and gonadotropic hormone	19	49.5	0.210	0.137
Gonadotropic hormone	17	48.7	0.206	0.137
Uninjected controls	13	51.2	0.021	0.036

TABLE 3. EFFECT OF EQUINE GONADOTROPIN ALONE AND IN COMBINATION WITH ASCORBIC ACID ON TESTES OF 70 DAY-OLD RATS

Treatment	Number of Rats	Average Body Weight at Autopsy	Average Weight of Testes
		gm.	gm.
Ascorbic acid and gonadotropic hormone	19	219	2.667
Gonadotropic hormone	15	238	2.776
Uninjected controls	19	247	2.636

TABLE 4. EFFECT OF EQUINE GONADOTROPIN ALONE AND IN COMBINATION WITH ASCORBIC ACID ON GENITALIA OF 70 DAY-OLD FEMALE RATS

	Number of Rats	Average Body Weight at Autopsy	Average Weight of Ovaries	Average Weight of Uterus
		gm.	gm.	gm
Ascorbic acid and gonadotropic hormone	15	176	0.632	0.572
Gonadotropic hormone	15	191	0.663	0.607
Uninjected controls	15	180	0.070	0.350

gonadotropin daily for 20 days no effects not obtained by pregnant mare serum alone were observed (tables 3 and 4). The gonads of the 24 day old rats showed highly significant increases in weight in the injected groups. The ovaries and uteri of the 70 day old animals were very responsive to gonadotropin but the testes of the males of similar age showed no significant weight increases.

Discussion

The reports of Phillips *et al.* (1940 and 1941) that the subcutaneous injection of ascorbic acid was of value in the restoration of fertility in certain impotent bulls and that similar treatment of cows was followed by the correction of some types of sterility have stimulated much research concerning the possible mechanisms of vitamin C in the regulation of the reproductive processes. The findings of Erb and Andrews (1942) that the injection of equine gonadotropin reduces blood plasma ascorbic acid in the bovine and the simultaneous report of Di Cio and Schteingart (1942) that ascorbic acid augments the gonadotropic hormone in the rat suggests the possibility that vitamin C may be a limiting factor in the response of the reproductive organs to gonadotropin. The fact that Di Cio *et al.* (1942) were unable to repeat Giedosz' results in the rabbit and that Andrews and Erb (1943) were unable to augment gonadotropin with ascorbic acid in the chick suggests that vitamin C does not uniformly produce augmentation.

The use of rats 2–4 months of age in gonadotropic hormone studies (Di Cio *et al.* 1942) is uncommon. Experience of workers in this and other laboratories indicates that the testis of the male rat exhibits all stages of spermatogenesis at approximately 50 days of age and gonadotropic hormone treatment at this time has little if any effect on testicular size. In the present experiment the average paired testis weights of the control and gonadotropin treated rats were 2.63 and 2.77 gm., respectively, in contrast to weights of 0.361 and 1.15 gm. for control and ascorbic acid-gonadotropin injected rats of between 2 and 4 months of age in Di Cio's experiments. Di Cio did not report the exact age of the animals but it is evident that there are very striking differences between the strain of rats which he is using in Buenos Aires and the colony of Wistar rats which we have utilized.

We have been unable to produce any augmentation of equine pregnancy serum gonadotropin with ascorbic acid. This finding, which is in contrast to the results of Di Cio and Schteingart (1942), suggests that (1) ascorbic acid does not produce uniform augmentation of the gonadotropic hormone (2) that the type of gonadotropin employed by Di Cio was unlike pregnant mare's serum (3) or that environmental and strain differences in our respective rat colonies were sufficiently great to account for the results obtained. It is hoped that other workers will conduct similar studies with the same and other species of animals.

Summary

The simultaneous injection of 50 mg. of ascorbic acid and 25 R.U. of pregnant mare serum gonadotropin in 24 day-old rats for 4 days and in 70 day-old rats for 20 days produced no greater increase in the weight of the

testes, ovaries or uterus than did the injection of 25 R.U. of gonadotropin alone.

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THE DEVELOPMENT OF BODY FORM IN SWINE[1]

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THE PRIMARY importance of conformation in swine is concerned with its effect on the consumer value of the market animal. It is frequently argued that it is also correlated with certain elements of productivity, e.g. fertility, rate of gain, or feed costs; however, at present there is little satisfactory evidence to indicate that such correlations are large enough to be of consequence so long as conformation remains within the range relatively acceptable for market purposes. Molln (1942) reported a partial correlation of only .13 between score and 180 day weight when scoring weight was held constant. Certainly the possibility of breeding more productive swine is greater through selection aimed directly at productivity rather than indirectly through type. Selection for type must, therefore, be evaluated solely in terms of what it accomplishes in increasing real market value.

Swine are marketed for the most part at weights ranging from 195 to 250 pounds. It is, therefore, within that range of weights that type is most important. Evaluations of type at other weights are useful to the extent that they predict the type of the animal's offspring or of the animal itself at market weight.

Careful observations of swine suggest that their type changes throughout the course of growth. McMeekan (1940) published supporting evidence based on the relative weights of major body parts at different ages. The study reported herein was made in a manner which would yield additional information on this point and at the same time demonstrate genetic differences in the way type changes as growth proceeds if such differences were present. The objective was to throw light on the usefulness of attempting to evaluate type at other than market weight.

Material

Winters *et al.* (1942) reported a study of seven measurements made on 85 boar-barrow pairs, 42 in 1939 and 43 in 1940. The members of each pair were litter mates. Pigs from six inbred Poland China lines and the Minn. No. 1 line (Winters, *et al.*, 1943) were included in the study. Measurements were taken at 8 weeks of age and every 4 weeks thereafter until one or both members of a pair weighed about 230 pounds or until the pigs were 180 days of age. The portions of that data involving body length, depth back of

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shoulders, width back of shoulders, and width of loin were used in the analyses reported herein. All pigs involved were self-fed the same rations.

Methods

D'arcy Thompson (1943) states " . . . the form of an organism is determined by its rate of growth in various directions. . . ." If the percentage growth rates of all the linear measurements of an animal are the same the animal does not change in form as it increases in size. Variation among the percentage rates of growth leads to modification of form or type as the animal grows.

The exponent, k, of the relative growth formula, $y = bx^k$ (Huxley, 1932) is the ratio of the percentage growth rates of measurements y and x. If they are equal, k will be one. Other values of k indicate inequality of percentage rates of the measurements involved.

The value of k for each of the six combinations of measurements taken two at a time was estimated by fitting the logarithms of measurements to the logarithmic form of the equation, $\log y = \log b + k \log x$.

There has been considerable discussion in the literature as to how generally the formula for relative growth adequately describes the comparative growth of parts or dimensions. However, in this case the point is immaterial since it does furnish the specific information desired, the average ratio of the percentage growth rates.

The process of fitting the data to the formula consisted of calculating the linear regressions of the logarithm of one measurement on the logarithm of another. The regression coefficients were then estimates of the corresponding k's. Kavanagh and Richards (1942) pointed out that this method of fitting, which minimizes errors in the dependent variable only, furnishes biased estimates of k unless the logarithms of the two measurements are perfectly correlated. The direction of bias depends on which measurement is considered the independent variable. When the correlation between $\log y$ and $\log x$ is perfect the regression of $\log y$ on $\log x$ is the exact reciprocal of that of $\log x$ on $\log y$. Such a close approach to this relationship was found here that use of the ordinary method was felt to be entirely justified. In most cases the deviation was less than .03.

Each combination of two measurements yielded two regression coefficients depending on which measurement was considered the independent variable. However, in view of the definite reciprocal relationship between them, only one for each pair of measurements need be considered further.

Separate regression coefficients were calculated from the data on each pig. Thus sets of 170 coefficients each were obtained. The variance within sets was then studied statistically. The data for each sex were analyzed separately in analyses of variance of the following form:

Source of variance	*D.F.*
Years	1
Breeds[4]	1
Lines within breed	5
Years×breed	1
Years×lines within breed	5
Total	13

The mean square for "Breeds" was compared to that for "Lines within breed" and the latter to that for "Years × lines within breed" to test the significance of breed and line differences, respectively.

The number of animals was not the same in both years for all lines. This caused the numbers in the year—line subclasses to be slightly disproportionate. The analyses were made, therefore, according to Snedecor's (1934) method for such data.

Results

The mean regression coefficients are presented in table 1 by sex, breed, and lines. The logarithms of body length, depth behind the shoulders, width behind the shoulders, and width of loin are referred to in both the table and the remainder of the text by the numerals 1, 2, 3 and 4 respectively.

The 12 means for each breed were tested for deviation from one using standard errors based on within line variation. Of the 24 only 4 were not significantly different from one. It can, therefore, be concluded at the outset that, since the measurements concerned are major ones in the definition of body form, type was changing continuously as the pigs grew. The direction and relative degree of changes during the phase of growth studied can be obtained from the table. For example, the means for the regression of 4 on 3 indicate that in both the Poland Chinas and the No. 1 line width of loin increases faster than width back of the shoulders. Thus a pig at eight weeks of age may be narrower in the loin than back of the shoulders yet be relatively uniform in width at market weight. The amount of change to be anticipated in this respect is greater in the No. 1 line than in the Poland Chinas.

Table 1 reveals that in Poland Chinas of both sexes depth of body increased at the fastest rate followed by width of loin, length of body, and width behind the shoulders in that order. In the No. 1 barrows the order was width of loin, depth of body, width behind the shoulders, and length of body; in the No. 1 boars, width of loin, depth of body, length of body, and width behind the shoulders.

The sex means for the No. 1 line fall outside the ranges for the Poland China lines except for the regressions of 2 on 1 for barrows and 2 on 1, 3 on 1, and 3 on 2 for boars and it is only in those cases that the difference between the No. 1 line and the Poland Chinas was not statistically signifi-

[4] The Minn. No. 1 line compared to the Poland China lines taken as a group

TABLE 1. MEAN* REGRESSION COEFFICIENTS INVOLVING THE LOGARITHMS OF BODY LENGTH (1), DEPTH BEHIND THE SHOULDERS (2), WIDTH BEHIND THE SHOULDERS (3), AND WIDTH OF LOIN (4) BY SEX, BREED, AND LINES

Regress of	Sex	Lines							
		P.C. 1	P.C. 2	P.C. 3	P.C. 4	P.C. 5	P.C. 6	P.C. Av.	No. 1
2 on 1	Barrow	1.198	1.141	1.072	1.150	1.114	1.141	1.147	1.153
	Boar	1.160	1.103	1.045	1.068	1.107	1.165	1.122	1.088
3 on 1	Barrow	1.008	.974	.950	1.014	.976	.961	.983	1.123
	Boar	.959	.929	.895	.942	.998	.993	.956	.967
4 on 1	Barrow	1.057	1.007	1.056	1.010	1.151	1.189	1.083	1.525
	Boar	.991	.940	.960	.898	1.062	1.149	1.011	1.344
3 on 2	Barrow	.838	.857	.890	.894	.879	.841	.859	.975
	Boar	.825	.835	.861	.882	.902	.853	.852	.885
4 on 2	Barrow	.885	.898	.985	.926	1.083	1.046	.961	1.323
	Boar	.856	.857	.918	.879	1.008	1.000	.915	1.227
4 on 3	Barrow	1.052	1.051	1.103	1.042	1.244	1.249	1.119	1.352
	Boar	1.031	1.020	1.067	.998	1.125	1.179	1.073	1.373

* The "expected" means since according to Snedecor and Cox (1934) they are the best available estimates of the true values.

cant. In those cases where the breed difference was significant the probability that it was due to chance was less than one percent except for the regressions of 4 on 3 for barrows and 4 on 1 for boars; there it was less than five per cent.

Variation among the Poland China lines was significant only for the regression of 4 on 1. The probability was less than one percent for boars and less than five percent for the barrows.

Further analysis showed significant differences between boars and barrows in three of the six cases in the Poland Chinas and in five cases in the No. 1 line. The sex differences for four of the regressions were significantly larger in the No. 1 line than in the Poland Chinas, but in only one instance did they vary significantly among the Poland China lines and in that case the probability was barely below five percent. These results were to be anticipated from the report of Winters *et al.* (1942) and verify their general conclusions that the development of form proceeds differently in boars than in barrows and that the difference is greater in the No. 1 line than in the Poland Chinas studied. The analyses involved are not presented in detail since they do not bear directly on the primary concern of this paper.

Discussion

The measurements involved in this study are only a few of those important in the definition of type. However, it is probably safe to assume that others would yield similar results. Likewise it is probable that if the same or other measurements had been taken during growth from market weight to maturity the results would not have been greatly different from those obtained prior to market weight. It is well known that unequal rates of growth are the rule during embryonic stages. It is unlikely that differential growth would occur throughout development from the ovum to market weight, but not thereafter. In like manner it is improbable that genetic differences in the way form develops would be present prior to attainment of a particular weight but not afterwards.

The important generalizations that appear justified are (a) that body form changes as animals increase in size since most of the relative growth constants were larger or smaller than one and (b) that there are genetic differences in the course of change in form since breed differences, and in one instance line differences, in relative growth constants were demonstrated. These are not surprising; indeed, they are what most swinemen would have predicted from their own observations. However, they have important implications and for that reason were worth verifying from systematically collected data.

Present practice emphasizes type evaluation of breeding animals not only at market weights but also at later stages of development. The question arises as to whether this does not unduly complicate the problem of producing swine satisfactory in conformation at market weight and at the same time superior in other characteristics. Should an animal having suitable form at 220 pounds be discriminated against later because at 500 pounds it deviated from a somewhat arbitrary standard of type for swine weighing 500 pounds? It appears that attempting to develop swine that will conform to a particular pattern of development with respect to body type requires a disproportionate amount of emphasis in selection. This would be particularly true if an attempt were made to impose on a genetic group of animals a pattern that was unnatural to that group. For example, if pigs of the Minn. No. 1 line were evaluated according to the average pattern of development demonstrated by the Poland China lines studied, it would be certain to interfere seriously with selection for performance since many animals among the best in performance and of satisfactory type at market weight would be culled on the basis of conformation at later stages.

It is common knowledge that breeders who exhibit swine at our livestock expositions frequently retain junior pigs less satisfactory from the standpoint of type standards believing they will come closer to the standards for

yearlings or aged swine than others more satisfactory as pigs. This alone suggests the difficulties involved in attempting to impose specific patterns of development on our breeds. The actual, though not intended, result is to encourage in many cases the retention of groups of animals varying in type rather than of animals that are uniform at least at market weight. It appears extremely unlikely that this system will lead to more uniformity of type in our breeds than has so far been attained.

It would appear more logical to evaluate conformation only at market weight and shift the emphasis now placed on type at other ages to direct selection for such characteristics as fertility and rate of gain. Progress towards uniform type in our market pigs should be no slower; it might be more rapid. A certain advantage would be the increased attention that could be paid to performance.

Summary

Swine change in form as they grow. The course of change in form is subject to genetic as well as environmental variation.

Boars and barrows were found to follow different paths of development with respect to conformation. The difference was greater in the Minn. No. 1 line.

It is suggested that swine improvement measured in terms of economically important characteristics would be more rapid if conformation were considered only at market weight and attention now given type at other ages were shifted to performance.

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A PRELIMINARY REPORT ON THE POST-NATAL DEVELOPMENT OF THE FIBER CHARACTERISTICS OF THE FLEECES OF NAVAJO SHEEP

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THE ANCESTOR of the domestic sheep presumably had a fleece consisting of two distinct coats, an outer coat of long, coarse, kempy fibers and an inner coat of short, fine wool fibers. The fleece was shed annually during the spring season. In the process of evolution the wooly undercoat has been developed until it now represents the main covering of improved breeds of sheep. However, sheep in all stages of wool improvement may still be found in various parts of the world. Wilson (1940) states that nearly half of the world's sheep population produces poor-quality wool of little commercial value, being hair-like in appearance and of low fleece weight.

Navajo sheep are a semi-improved type similar to those found in Mexico and many South American countries. Their fleeces consist of an undercoat of fine wool fibers and varying amounts of coarse outercoat, kemp, and other medullated fibers. The various types of fiber differ greatly in physical properties and also in growth characteristics. Hence the character of the fleece changes rapidly during growth, particularly in the first few months when coarse birth coat fibers are being shed and new wool fibers developing.

In breeding for wool improvement, it is important to determine the optimum age for evaluating quality of the fleece. Thomasset (1938) reported that the fiber characteristics of the lamb fleece give a better idea of the genetic makeup of the animal than those of the adult sheep. He recommended that the lamb fleece be examined in a late-developing region, such as the tail. Lambs having fewest undesirable fibers at the earliest age were considered the most improved. The purpose of this paper is to present the results of a preliminary study of the fiber characteristics of Navajo fleeces at periodic intervals of growth up to one year of age.

Materials and Methods

Fifteen Navajo ewe lambs born from May 11 to 15, 1940 in the breeding flock at the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, N. Mex., were used for this study. Small fleece samples were collected from the side, thigh, and back of each lamb at 13 different ages ranging from 28 to 364 days. An effort was made to obtain the samples at 28-day intervals

[1] This study was conducted under authority of the Bankhead-Jones Act, in cooperation with the Bureau of Indian Affairs, United States Department of the Interior.

of growth, but weather conditions during the winter sometimes made it necessary to postpone the sampling for one or more days.

All samples were analyzed in the laboratory to determine the percentage of wool, hair, and kemp fibers. A total of 100 fibers from each sample was hand-separated and classified by type according to their macroscopic characteristics. The wool, hair, and kemp fibers were placed in separate groups and carefully aligned so that all fibers might be cross-sectioned in the same plane and as close as possible to their base ends. Hardy's (1933) device was used for sectioning the fibers and their average diameters were measured from a magnified image of the cross sections by the methods reported by Grandstaff and Hodde (1940). The statistical procedures used in analyzing the data are discussed in connection with the experimental results.

Data and Discussion

Figure 1 shows the average diameter distribution in microns of wool, hair, and kemp fibers for the 585 samples used in this study (representing side, thigh, and back samples from 15 lambs at 13 different ages). Measurements on a total of 44,709 wool fibers, 8,739 hair fibers, and 2,598 kemp fibers were

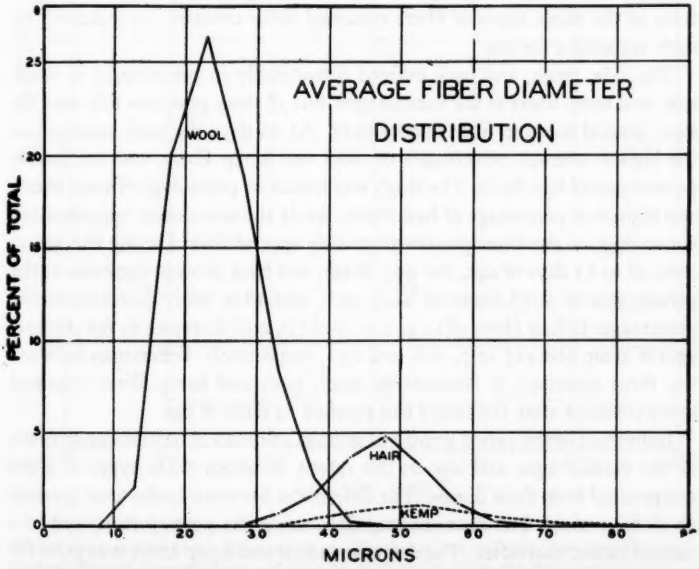

Figure 1. Average diameter distribution of three types of fibers, based on total fiber measurements of fleece samples taken at periodic intervals from 28 days to one year of age.

used in plotting the respective curves, each of which is expressed in percentage of the total of all three types of fibers. It will be noted that the distribution for hair and kemp fibers falls largely to the right of the distribution for wool fibers, but there is some overlapping of the three curves between 35μ and 45μ. Kemp fibers are the most variable in diameter, but most of them fall within the range of the hair fibers. Wool fibers amount to 79 per cent of the total, while hair and kemp represent 16 and 5 percent, respectively, for the combined 13 ages. It is evident from this graph that the hair and kemp fibers have a dominant influence on fleece quality, because of their coarseness and variability in diameter.

Growth of the fleece was accompanied by marked changes in the relative amounts of wool, hair, and kemp fibers in the three different regions of the fleeces. The average percentage of each type of fiber at various ages ranging from 28 to 364 days is shown in figure 2. Samples from side, thigh, and back positions at 28 days of growth contained an average of about 60 percent wool, 24 per cent hair, and 15 per cent kemp fibers by number. The period from 28 to 84 days of age was one of rapid fiber change, characterized by a 21 percent increase in wool fibers and decreases of 9.5 and 10.5 percent, respectively, in hair and kemp fibers. From 84 to 364 days of age the proportions of the three types of fibers remained fairly constant, as indicated by their respective curves.

The side, thigh, and back differed considerably in percentages of wool, hair, and kemp fibers at the various ages, but all three positions followed the same general trend in fiber development. At 28 days the back samples had the highest average percentages of wool and kemp fibers, and the lowest percentages of hair fibers. The thigh was lowest in percentage of wool fibers, and highest in percentage of hair fibers, while the side closely approximated the average of the three positions for each type of fiber. During the period from 28 to 84 days of age, the side, thigh, and back showed increases in the percentages of wool fibers of 21.1, 23.0, and 18.9, with decreases in the percentages of hair fibers of 10.4, 13.1, and 5.8, and decreases in the percentages of kemp fibers of 10.7, 10.6, and 13.1, respectively. Differences between the three positions in amounts of wool, hair, and kemp fibers remained fairly constant after the lambs had reached 84 days of age.

Individual lambs varied greatly in average amounts of hair and kemp fibers at the various ages, and also in the extent to which these types of fibers disappeared from their fleeces. The differences between lambs were greatest at 28 days of age but decreased rapidly during the next 56 days, and to a limited extent thereafter. The decrease in hair and kemp fibers was great for some lambs and moderate or low for others. The significance of these facts is not clear at this time, but it is believed that the differences in fiber develop-

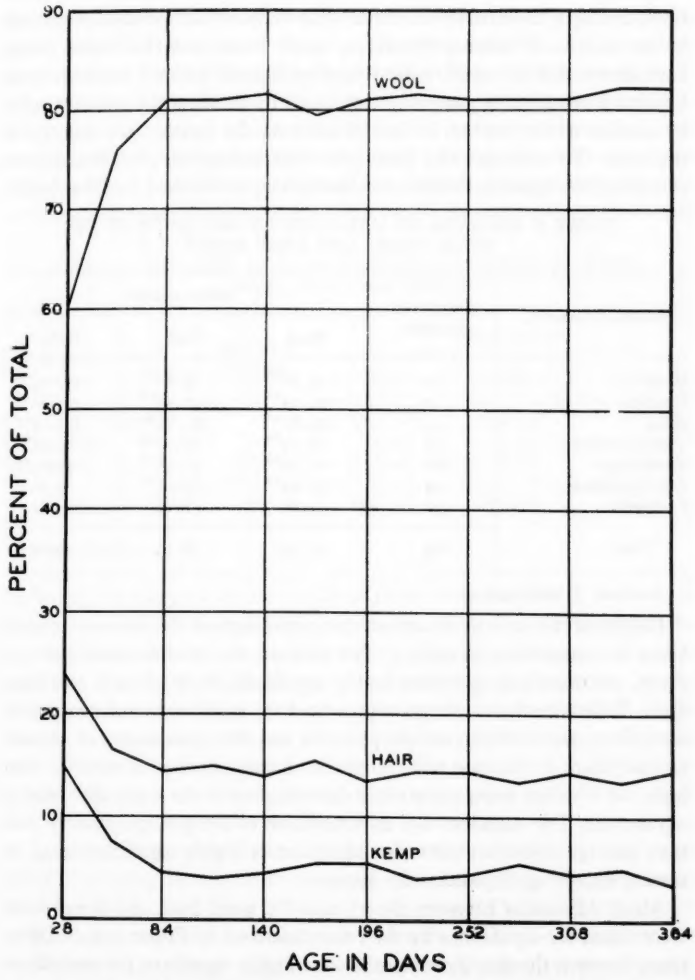

Figure 2. Average percentages of three types of fibers in fleece samples obtained from lambs at 13 different ages. These curves indicate that the fiber content of Navajo fleeces does not change materially after the first few months of growth.

ment of the lamb fleeces were governed to a large extent by genetic factors.

In order to evaluate precisely the differences between sheep, fleece positions, and ages, the data for the three types of fibers were studied separately by an analysis of variance (Snedecor, 1937). Baten and Henderson (1940) have shown that the usual application of analysis of variance methods is not legitimate in analyzing percentages obtained by dividing the whole number by another whole number. In data of this kind the variance is a function of the mean. To overcome this functional relationship the percentages were converted to angles by Fisher's transformation, as reported by Bliss (1938).

TABLE 1. ANALYSIS OF VARIANCE OF PERCENTAGES OF WOOL, HAIR, AND KEMP FIBERS

Source of variance	Degrees of freedom	Mean squares		
		Wool	Hair	Kemp
Sheep	14	53.81**	78.84**	430.49**
Positions	2	271.94**	615.96**	395.46**
Ages	12	622.61**	181.14**	545.13**
Sheep×positions	28	8.94**	17.02**	13.48*
Sheep×ages	168	21.36**	21.10**	25.73**
Age×positions	24	21.97**	12.91**	9.36
Remainder	336	4.83	6.26	8.21
Total	584	23.41	18.74	36.04

* Significant; ** highly significant.

Results of the analysis of variance for percentages of the different types of fibers are summarized in table 1. The variance due to differences between sheep, positions, and ages were highly significant for wool, hair, and kemp fibers. Differences between ages represented the major source of variance for wool fibers, and between sample positions was the major source of variance for hair fibers. In the case of kemp fibers, all three sources of variance were high, the F values being many times that required at the 1 per cent level of significance. The variances due to interaction of sheep×age, sheep×position, and age×position were also significant or highly significant in all instances except age×position for kemp.

Mean differences between the 13 ages for wool, hair, and kemp fibers were tested for significance by the t test described by Fisher (1934). Differences between the first three months were highly significant for wool fibers, and differences between the first two months were highly significant for hair and kemp fibers. Differences between the means of the remaining ages were not significant in any case. These results indicate that the fiber development of the fleece, namely the shedding of coarse birth coat fibers and production of new wool fibers, had been largely completed at 84 days of age.

In comparing the fiber-diameter distribution for the 13 different ages, it was observed that the wool and hair fibers tended to get finer during the first 5 or 6 months and gradually to increase in diameter during the remainder of the year. The distribution for kemp fibers was variable but followed no definite trend. To test the significance of the variance in diameter distributions the data for each type of fiber were analyzed by analysis of variance. Frequency distribution of the diameter measurements for wool, hair, and and kemp fibers was first summarized in class intervals of 5μ and each figure converted to a percentage of the total for all three types of fibers. For the analysis of variance the percentages were translated into angles as previously

TABLE 2. ANALYSIS OF VARIANCE OF DIAMETERS OF WOOL, HAIR, AND KEMP FIBERS

Source of variance	Degrees of freedom	Mean squares		
		Wool	Hair	Kemp
Between class intervals	5	1213.78**	146.69**	17.40**
Between ages	12	6.04	4.10	7.94**
Remainder	60	7.42	8.02	1.23
Total	77	6586.35	1263.78	288.45

** Highly significant.

explained. A summary of the results of these analyses, table 2, shows that the variance in diameter distribution due to differences between ages was not significant for wool and hair, but highly significant for kemp fibers. It appeared that the results for kemp were due largely to the variance in the first samples taken at 28 days of age, so a separate analysis was made of the data for the remaining 12 ages. The F value then obtained was not significant. This implies that changes in fleece quality after the first month were due to differences in the proportions of wool, hair, and kemp fibers, rather than changes in their respective diameter distributions.

Results of this study indicate that the proportions of wool, hair, and kemp fibers in yearling Navajo fleeces are fairly well established when the lambs have reached 84 days of age. Hence this would seem to be the earliest age at which fleece quality could be evaluated with sufficient accuracy for use in the breeding program. On the other hand, it appears that the large differences observed between the fleeces of the lambs at 28 days of age may reveal genetic differences which are later obscured. If this is true, it would be advantageous to make an evaluation of the fleeces at or before 28 days of age. The answer to this important problem can be determined only through carefully planned breeding tests in conjunction with the fleece studies.

Summary

Fleece samples obtained from side, thigh, and back of 15 Navajo ewe lambs at periodic intervals of growth ranging from 28 to 364 days were analyzed for percentages of wool, hair, and kemp fibers, and the diameter-distribution of each type of fiber was measured.

Samples at 28 days of growth contained an average of approximately 60 per cent wool, 24 per cent hair, and 15 per cent kemp fibers by count. During the next 56 days wool fibers increased 21 per cent, while hair and kemp fibers decreased 9.5 and 10.5 per cent, respectively. From 84 to 364 days proportions of the three types of fibers remained relatively constant. Side, thigh, and back samples followed the same trend in fiber development.

Differences between lambs were greatest at 28 days of age, but decreased rapidly during the next 56 days and to a limited extent thereafter, which suggests the influence of genetic factors.

Highly significant differences were found between sheep, positions, and ages in percentages of wool, hair, and kemp fibers. Age differences were due to sharp changes in fiber content of the fleeces during early months of growth.

The diameter-distributions of wool and hair fibers did not change significantly during the year, but kemp showed a significant change in this respect between the 28 and 56 day samples.

The significance of these facts is not clear at this time. The study should be continued in conjunction with carefully planned breeding tests.

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SELECTION FOR GROWTH RATE OF PIGS AND PRODUCTIVITY OF SOWS[1]

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United States Department of Agriculture

Introduction

GROWTH rate of pigs and productivity of sows are important traits that the swine breeder seeks to improve. The purpose of the present study is to answer the following questions concerning selection for these traits: (1) What proportion of the boar and gilt pigs should be kept until post-weaning growth rate is obtained; (2) what age composition of the sow herd is optimum; and (3) how is rate of improvement affected if sows produce two litters per year instead of one? The genetic improvement to be expected from successive cullings at different ages was computed largely by formulas given in a previous publication (Dickerson and Hazel, 1943). These are not repeated here.

Weight at 180 days of age is used as the measure of growth rate, although a weight taken earlier may prove equally satisfactory (Baker *et al.*, 1943). The index suggested by Lush and Molln (1942) is used as the measure of sow productivity.

In calculating total genetic improvement for the two traits, an increase of one unit in the productivity index is considered as valuable as an increase of six pounds in weight at 180 days. This is based on a study by Lush (1940) indicating that one additional pig weaned per litter (the equivalent of approximately 4 units in the productivity index) is worth about as much as 25 pounds more weight per pig at 180 days.

Effect of Culling Pigs at Weaning

At weaning, pertinent information concerning a pig's breeding value for growth rate and productivity (H) includes his own 56-day weight (X) and the productivity index of his dam (P'). The most accurate index of breeding value combining these two traits was found to be $I_1 = X_1 + P'$.[3] This index and the others which follow were calculated by the multiple regression method outlined by Hazel (1943), from the statistics given in tables 1 and 2.

[1] Journal paper No. J-1148 of the Iowa Agricultural Experiment Station, Ames, Iowa, in cooperation with the Regional Swine Breeding Laboratory, Bureau of Animal Industry, and the Nebraska Agricultural Experiment Station. Project 32.

[2] The authors are, respectively: associate geneticist, Regional Swine Breeding Laboratory, Ames, Iowa; and assistant animal husbandman, Regional Sheep Breeding Laboratory, Dubois, Idaho, Bureau of Animal Industry. Suggestions concerning the presentation of this study by Drs. Jay L. Lush and W. A. Craft are gratefully acknowledged.

[3] In the selection indexes presented, P represents the probable real deviation of the sows productivity index from the herd average for all sows with litters at the same ages. P is calculated as shown by Lush and Molln (1942) in their tables 17 and 18 except that the points given per unit of deviation are proportional to $.18/[K(.18)+.82]$ rather than to $1/(K+5)$, where K is the number of litters for the sow.

In addition to those statistics, it was assumed that the genetic and environmental correlations between dam's productivity index and 56-day weight or 180-day weight were zero (see Bywaters, 1937, and Hazel, 1943, respectively, for supporting evidence). The case in which P' is based on a single litter was considered first. The correlation between total breeding value and the index for culling at 56 days (r_{I_1H}) turned out to be 0.225. Thus the accuracy of I_1 was less than one-fourth that of a perfect index.

TABLE 1. APPROXIMATE VARIANCE AND HERITABILITY FOR 56-DAY WEIGHT, 180-DAY WEIGHT AND PRODUCTIVITY INDEX, WITHIN A SINGLE HERD AND FARROWING SEASON

Trait	Variance	Heritability
56-day weight of pigs (X)	64[1,2]	0.15[2,3,5]
180-day weight of pigs (W)	1038[1,3]	0.30[1,2,5]
Productivity index of sows (P) with one litter each	97[3,4]	0.18[3,4]

[1] Whatley, 1942.
[2] Bywaters, 1937.
[3] Hazel, 1941.
[4] Lush and Molln, 1942.
[5] Baker et al., 1943.

For selections made after 180 days of age, the most accurate index was $I_2 = 0.56W + P'$. Little accuracy would be added by including the average 180-day weight of the litter, because of the rather large environmental correlation (.2) between littermates for this trait (see Lush, 1943, pp. 310–317). Increasing the intensity of earlier culling on $I_1 = X + P'$ has practically no effect on the weight which should be given W and P' in calculating I_2, since the proper adjustment results automatically from the reduced variability of P'. However, this same reduction in variation of P' causes the accuracy of I_2 (as measured by r_{I_2H}) to decline from 0.36 to 0.29, as the proportion discarded at 56 days is increased from 0 to 11/12). I_2 is more accurate than I_1 because 180-day weight is more accurate than 56-day weight as a measure of breeding value for growth rate ($r_{G_WW} = \sqrt{.30}$ and $r_{G_WX} = .64\sqrt{.15}$, tables 1 and 2).

TABLE 2A. CORRELATIONS BETWEEN CORRESPONDING SOURCES OF VARIATION IN 56-DAY AND 180-DAY WEIGHTS

Source of variation	Nebraska data	Iowa data	Average
Genetic merit or transmitting ability	.73	.54	.64
Environment influencing the litter as a whole	.72	.68	.70
Random environment and gene interactions	.34	.58	.46
All sources	.52	.57	.55

2B. DEGREES OF FREEDOM FOR ANALYSIS OF COVARIANCE FROM WHICH CORRELATIONS WERE CALCULATED[1]

Source of variation	Nebraska data	Iowa data
Between sires within seasons	54	25
Between litters by same sire	197	176
Between litter mates	735	846

[1] For method of calculating such correlations see Hazel, *et al.* (1943).

The more intense the first culling the less intense the second can be. Since the second index is more accurate than the first, maximum improvement from boar selection can be attained only by postponing all culling until 180 days of age. Figure 1 shows how the genetic superiority of the boars selected varies with the amount of culling at weaning, for the case in which two boars are finally picked from 60 weaned and P' is based on a single litter.[4] If final selections are made at weaning, only about three-fifths as much improvement is expected as if all culling were postponed until 180-day weights were obtained. However, considerable culling can be practiced as early as 56 days without reducing the actual improvement *much*, as compared with the maximum. Little is lost by culling up to two-thirds of the pigs at 56 days, but more severe early culling seriously reduces improvement. In general, it seems that only a small proportion of the maximum improvement will be lost by early culling of boars, if the number kept to 180 days is from 8 to 10 times the number finally needed.

Curves for a group of any size would be similar to those shown in figure 1 if the proportion finally selected comprised about 1/30 of the original group. If the final proportion were greater than 1/30, less culling could be done at 56 days without reducing progress appreciably. For this reason less early culling would be advisable among gilts than among boars. For example, if $\frac{1}{6}$ to $\frac{1}{3}$ of the gilts weaned are needed for breeding, at least $\frac{2}{3}$ of them, or about 3 times the number needed, should be retained until 180-day weights are obtained.

Improvement from boar culling consists of improvement in growth rate and in productivity (figure 1). The proportions of each shift with the intensity of first culling. In culling at 56 days the superiority of the selected

[4] The superiority in H of 2 boars selected from 60 in figure 1 is calculated as $\Delta H = (i_1 r_{HI_1} + i_2 r_{HI_2})\sigma_H$ for each proportion of boars culled at 56 days, where i_1 and i_2 are the selection differentials (in standard deviations) expected from culling done at 56 and at 180 days, respectively. In each case, the portions of the total superiority in H comprised by that in W and in P is calculated in units of H as

$$\Delta H_W = \frac{\sigma_{G_W}}{6}(i_1 r_{GWI_1} + i_2 r_{GWI_2}) \text{ and as } \Delta H_P = \sigma_{GP}(i_1 r_{GPI_1} + i_2 r_{GPI_2}),$$

respectively.

group in breeding value should average about 2.8 pounds in 180-day weight and 0.68 point in productivity above the unselected group, for each standard deviation of superiority in I_1 (P' based on one litter). In culling at 180 days, the figures for the two traits are 8.5 pounds and 0.43 point, respectively, if no culling was practiced at 56 days. If the intensity of first culling is in-

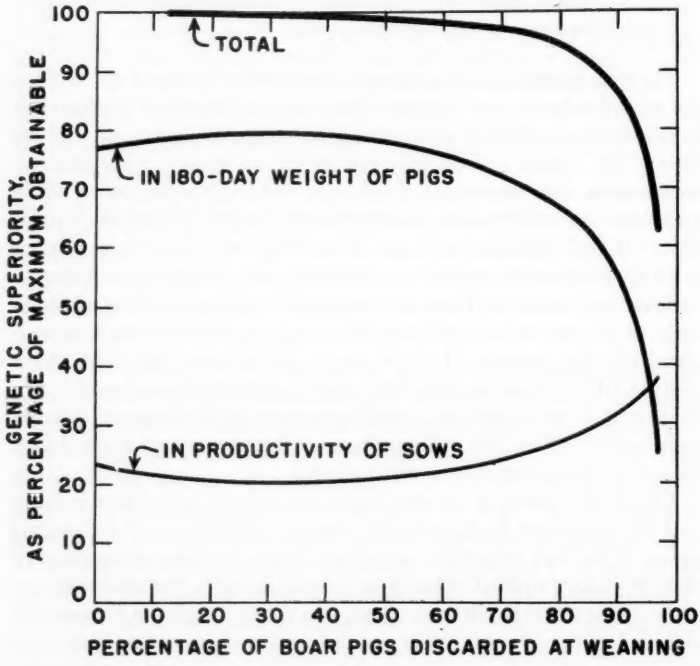

Figure 1. Influence of culling boars at weaning on effectiveness of boar selection.

creased from 0 to 11/12, the latter figures change to 8.6 pounds and 0.04 point, respectively. This differential emphasis upon improvement in the two traits with changes in the intensity of early culling occurs because no new information concerning breeding value for productivity is contained in the second index. Both indexes are constructed so as to make *maximum* improvement from selection with the information at hand (always supposing that 6 pounds in growth rate is worth 1 point in productivity). Because 180-day weight is more accurate than 56-day weight as a measure of breeding value for growth rate, a larger proportion of the total improvement is in

productivity when early culling is severe (figure 1). If severe culling is delayed until 180-day weights are available, a larger proportion of the total improvement is in growth rate.

Weaning weight does, however, provide some information on growth rate not contained in the 180-day weight. Hence, total improvement in growth rate is greater when some culling is done at weaning than when only 180-day weight is used. This explains the slightly increased improvement in growth rate, at the expense of improvement in productivity, as the per cent culled at weaning rises from zero toward 30 (figure 1).

When sows are bred to farrow every 6 months, the productivity of the dam in a subsequent litter provides previously unused information in time for the second culling at 180 days. If the productivity of each dam could be based on the average of 2 litters, the maximum progress from selecting the boars would be increased nearly 8 per cent over the previous case. The extra gain would be in productivity, brought about to some extent at the expense of improvement in growth rate. This additional information about productivity for the culling at 180 days makes intense culling at 56 days a little more likely to decrease the actual improvement, as compared with the maximum, than when no new information concerning productivity becomes available between weaning and the final culling.

Effect of Culling Less Productive Sows

The proportion of the sows which have previously produced one or more litters may be varied from zero to the maximum permitted by losses from death and unsoundness. Information concerning breeding value usually increases with age, so that selection is more accurate among older animals. In addition, the longer sows are kept in the breeding herd, the more highly selected can be the gilts used to replace them. These factors are offset (at some point) by the longer interval between generations and by the less intense culling among sows when more of them are retained for breeding. The optimum proportion of older sows for breed improvement is presumed to be the one for which yearly improvement is maximum.

The analysis which follows shows how yearly improvement is affected by the age composition of the sow herd and by the number of farrowing seasons each year. Several selection plans, differing in the age of sows at culling and in the interval between farrowing seasons, are examined.

We first consider in detail the case of a 20-sow herd which averages 6 pigs raised per litter, assuming that breeding stock is selected equally from spring and fall litters and that the two boars used each season are 1 year old when their offspring are born. In plan 1*a* the dam's productivity is based on one litter. Gilts and boars are selected with the index $I_2 = 0.56W + P_1'$

(subscripts indicate number of litters for P). Sows are culled after weaning their first litters on I_2 and the sow's own productivity (P_1), the best index being $I_3 = I_2 + 2.0\ P_1$. The better sows are retained only long enough to produce a second litter 6 months after the first.

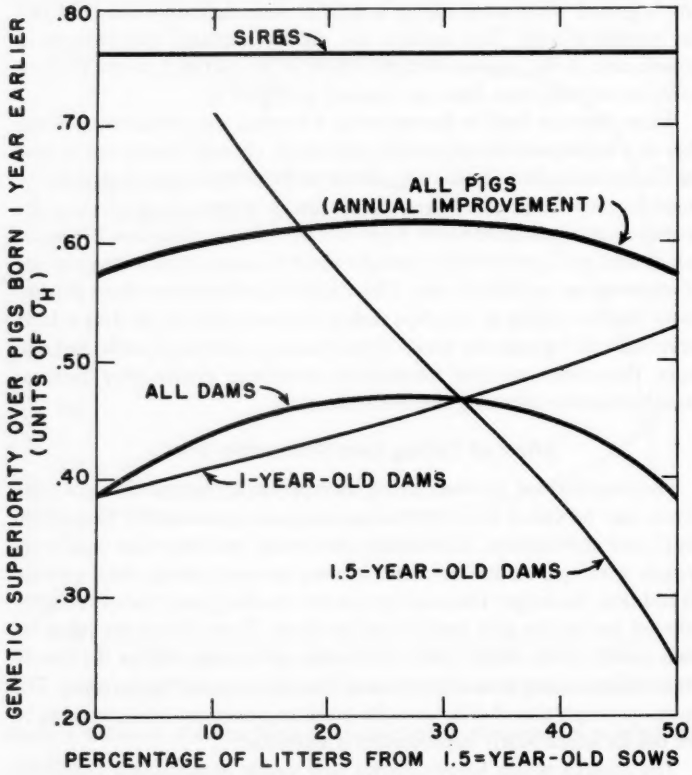

Figure 2. Results expected from keeping more sows for a second litter.

Figure 2 shows the genetic superiority expected under plan 1*a* for the different groups of parents and offspring, as compared with the pigs born one year earlier.[5] Genetic superiority for 1-year-old increases as the number

[5] The curves in fig. 2 were calculated as follows: The indexes for the two best out of 60 pigs will average 2.12 standard deviations above those for the entire group (obtained from a table of values for the normal curve and small populations). The part of this apparent superiority of the two pigs which is *genetic* is proportional to the accuracy of the index. Thus the two 1-year-old boars used average $2.12 \times 0.36 = 0.763\sigma_H$ above the pigs born the previous year.

of 1.5-year-old sows becomes larger because more intense selection can be practiced in choosing the smaller number of gilts needed when more of the older sows are kept. At the same time, the curve for the 1.5-year-old sows decreases sharply because a larger number must be selected from a smaller group of young sows. The proportion of sows and gilts is optimum (i.e. the average superiority of all dams is maximum) when the superiority of the two groups is equal. For this to happen, enough genetic superiority must be obtained from culling among sows to make up for the improvement which took place in the herd during the interval between birth dates for the sows and the gilts (in this case, during a 6-month period). In this example, about 7 per cent more progress can be made by keeping 5 or 6 of the best sows for a second litter than by using only gilts for breeding.

With optimum use of the plan just outlined (1*a*), about 25 or 30 per cent of the pigs will be from 1.5-year-old sows, and a still larger percentage will be from the 1-year-old sows which are productive enough to be kept for a second litter 6 months later. Thus more than half of the pigs will be from dams which have produced 2 litters by the time final selections of gilt and boar pigs must be made. Probably all the boars and most of the gilts considered for breeding will be from these dams, so that the dams' productivity could be based on two litters for selecting among them. In this event (plan 1*b*) the best indexes are $I_2 = .56W + P'$ for boars and gilts and $I_3 = I_2 + 2.0\,P_1$ for sows. If all selections are made with the two latter indexes, the optimum proportion of older sows is reduced only slightly, but the advantage of keeping the best sows for a second litter (as compared with using gilts only) is raised from 7 per cent to 15 per cent. Actually, a few gilts and very rarely a boar might be saved from sows that were culled after their first litter. Therefore, the yearly progress expected from plan 1*b* would be slightly lower in practice than indicated above. Only rarely would any of the 1.5-year-old sows be good enough to merit keeping for additional litters.

The results to be expected from several plans for culling sows are summarized in table 3. Plans 1*a* and 1*b* have been discussed. Since sow culling is delayed until the first litter is at least 6 months old in plans 2, 3 and 4, the average 180-day weight for each sow's first litter ($\overline{W}$) is included in the

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The selection intensity for gilts varies inversely with that for sows. When the 6 best sows are retained, the 14 best gilts out of 60 average $1.29 \times 0.36 = 0.463\sigma_H$ above the whole group. The genetic superiority of the 6 best sows above the group in which they were born is $0.787\sigma_H$. This is made up of $0.463\sigma_H$ from their selection as gilts plus the additional gain of $0.324\sigma_H$ from the subsequent selection of the 6 best among the 14 which produced first litters. Weighting the three groups according to the portions of inheritance they contribute to the offspring, the average genetic superiority of the pigs is $[0.763 + 0.7(0.463) + 0.3(0.787)]\sigma_H/2 = 0.662\sigma_H$. Since the average age of parents is $1 + 0.7(1) + 0.3(1.5)/2 = 1.075$ years, the genetic progress per year is $0.662\sigma_H/1.075 = 0.615\sigma_H$. Therefore, the 1.5-year-old dam's average $0.787\sigma_H - 0.615\sigma_H/2 = 0.480\sigma_H$ over the pigs born the previous year. This process must be repeated for each number of 1.5-year-old dams from 0 to 10. In each case the number of gilts saved must be adjusted to make a total of 20 females.

index as additional information concerning her breeding value. Plans 2 and 3 differ from plan 1 in that sow culling takes place after weaning the second litter, so that productivity in 2 litters instead of one may be used for culling sows as well as pigs. The basis of culling is the same for plans 2 and 3, but no replacements are saved from fall litters in plan 3. In plan 4 only spring litters are produced; hence productivity is based on the first litter only.

TABLE 3. COMPARISON OF DIFFERENT PLANS FOR CULLING AMONG SOWS

A. Plans considered

Plan	Number of litters			Basis of culling[2]			
	per year	from sows culled	from sows kept	Gilt and boar pigs		Sows	
				Index (I_2)	r_{I_2H}	Index (I_3)	r_{I_3H}
1*a*	2	1	2	$.56W+P_1'$	.36	$I_2+2.0P^1$	.37
1*b*	2	1	2	$.56W+P_2'$	.39	$I_2+2.0P_1$	.37
2	2	2	3–4	$.56W+P_2'$	.39	$I_2+.58\overline{W}+2.3P_2$	.48
3	2[1]	2	3	$.56W+P_2'$	.39	$I_2+.58\overline{W}+2.3P_2$	.49
4	1	1	2	$.56W+P_1'$	.36	$I_2+.52\overline{W}+2.2P_1$	.41

[1] Breeding stock saved from spring litters only.

[2] W = 180 day weight of pig; $\overline{W}$ = average W for sow's first litter; P_1 = deviation of sow's productivity index in one litter; P_2 = deviation of productivity in two litters; the primes refer to the pig's dam.

B. Results expected

Plan	Optimum per cent of older sows in herd	Yearly improvement in units of σ_H[1]		Percentage increase of 2 over 1
		1. If only gilts were bred	2. If per cent of older sows is optimum	
1*a*	25–30	.57	.62	7
1*b*	25–30	.57	.66	15
2	10–15	.62	.63	2
3	15–20	.62	.64	4
4	10–15	.57	.59	3

[1] One σ_H = 5.11 units in H, and each unit in H is the equivalent of 6 pounds in W or 1 point in P. Thus in plan 1b, the $.66\sigma_H$ consists of 12.6 pounds in 180-day weight and 1.27 points in the productivity index (about ⅕ of a pig per litter at weaning).

In plans 1*a* and 1*b* the average interval between generations is not increased as much by retaining the better sows as in plans 2, 3 and 4, because the twice-selected sows farrow their litters when only 6 months older than the once-selected gilts in plans 1*a* and 1*b*, whereas the time lapse is more nearly 1 year in the other plans. For this reason, the gain from keeping the optimum number of older sows instead of breeding only gilts (table 3*B*) is

greater for plan 1 (7 to 15 per cent) than for the other plans (2 to 4 percent). For the same reason, a larger proportion of the older sows is optimum under plan 1 (25 to 30 per cent compared with 10 to 20 per cent).

Having two farrowing seasons each year increases the accuracy of selecting boars and gilts. Even if none of the better sows are kept for additional litters at sow culling time, yearly progress is $0.62\sigma_H$ when dam's productivity is based on two litters as compared with $0.56\sigma_H$ when it is based on only one litter. This difference accounts for most of the advantage which plans 1*b*, 2 and 3 have over plan 4.

Yearly improvement is greatest from plan 1*b*. However, plans 2 and 3 are nearly as good. It makes little difference whether replacements are obtained from spring and fall litters (plan 2) or from spring litters only (plan 3). However, it is important to have fall litters produced so that pigs may be culled on the dam's productivity in 2 litters instead of one. Thus in breeding experiments with inbred lines, fall litters could be used for testing crosses without hampering appreciably selection within the lines. Plan 4 ranks last because productivity must be based on a single litter in culling among sows and among most of the boars and gilts. The extra progress obtained by keeping the optimum number of the best sows to farrow a second litter 1 year after the first is so small (3 per cent) that it probably would not justify maintaining these sows open until fall breeding.

Application to Other Conditions

A number of factors may influence the amount of yearly improvement and change the optimum proportion of older sows to be kept. These factors depend partly upon circumstances peculiar to each herd. Consequently, no rules cover *all* herds.

Under the best plan of selection for growth rate and productivity considered here (1*b*, table 3), the rate of improvement expected each year was $.66\ \sigma_H$. This annual increase consisted of 12.6 pounds in 180-day weight of pigs and 1.27 points in the productivity index of sows (roughly one-third of a pig per litter at weaning). This is the maximum progress that could be expected. Progress in these traits would be slower in practice because only part of the culling could be directed toward their improvement. Other factors, such as lower heritability of the traits, less opportunity for culling because of smaller litters, and decline in performance with a rise in inbreeding, also might make progress slower than was calculated here.

There is less room to cull for other reasons among sows than among pigs, particularly among boar pigs. Hence, the optimum proportion of older sows would be slightly smaller than stated here if such culling were as prevalent among sows as among gilt and boar pigs. Of course, any factors which would

make culling among boar or gilt pigs relatively less effective than among sows would make the optimum proportion of sows larger than postulated for the plans considered (table 3*B*). For example, boar selection would be relatively less effective than gilt and sow culling if an excessive proportion of the boars were culled before a good measure of growth rate was obtained. Bringing in boars from outside herds is likely to have a similar effect, except in the poorer herds, because herd differences in environment and management make inter-herd comparisons of breeding animals less accurate than intra-herd comparisons. Also, small size of herd might tend to make selection relatively less intense among boars than among gilts and sows, since one boar is needed in even the smallest herd.

Average size of litters would vary from herd to herd for both genetic and environmental reasons. This would reduce or increase the selection intensity that could be practiced for gilts and boars but would not change the selection of sows based on their own performance. Fewer than 6 pigs weaned per litter would result in less annual progress and a higher optimum proportion of older sows than stated here.

In small herds closed to outisde breeding, the actual yearly improvement under the various plans of sow culling presumably will be less than was calculated here because of the reduction in performance which is expected to accompany a rise in inbreeding. Whatley (1942), for example, found a 0.76 pound decline in 180-day weight for each 1 per cent increase in inbreeding among pigs born in the same farrowing season. Thus part of all of the gain from selection may be required to offset the loss from inbreeding. However, these effects of inbreeding do not change the optimum plan of selection, since improvement masked by inbreeding is expected to reappear when the inbred lines are crossed with each other or topcrossed on outbred stock.

Heritability was estimated here at 30 per cent for growth rate of pigs and at 18 per cent for productivity of sows. If heritability were lower for both traits, improvement would be slower, but this would cause little or no change in the optimum proportion of older sows or in the percentage advantage of retaining the better sows longer. True, there would be less herd improvement in the interval between birth of sows and gilts, which must be compensated for by selection among the sows in order to make average genetic merit equal for sows and gilts bred. However, the effectiveness of culling sows would be reduced in essentially the same proportion as the rate of herd improvement. Lower heritability would tend to reduce accuracy of culling less for sows than for pigs only to the extent that averages for sow productivity or growth rate of progeny were used more for culling among sows than in selection of pigs.

Errors in estimating heritability *will* change the computed optimum proportion of older sows if they are larger or in a different direction for growth rate than for productivity. For example, if heritability is 30 per cent for growth rate, but is 10 instead of 18 per cent for productivity, the accuracy of culling is reduced more among sows than among pigs and a smaller proportion of older sows would be optimum.

Results from more than two successive cullings at different ages are not considered here because of the complexity of the calculations. Obviously, some of the best sows in the group selected at the second culling should be retained for still another litter if they are superior to any of the gilts or younger sows which would be used to replace them. However, the optimum proportion of all sows to be obtained from the third and later cullings seems bound to be almost negligibly small because of the extremely limited opportunity for culling within these older groups.

Summary

The effectiveness of different methods of selecting for improved growth rate of pigs and productivity of sows is compared. Data used are from the Iowa and Nebraska Station swine herds maintained in cooperation with the Regional Swine Breeding Laboratory.

From 8 to 10 times as many boars, and about 3 times as many gilts, as are needed for breeding should be retained long enough after weaning to obtain a measure of growth rate that is more reliable than weaning weight. The rest may be culled at weaning without reducing the effectiveness of selection appreciably.

Several plans for culling sows, differing in the number of litters produced before and after culling and in the number of farrowing seasons each year, are compared. Yearly progress from selection is greatest when sows are culled after the first litter, the best $\frac{1}{3}$ to $\frac{1}{2}$ being kept for a second litter 6 months after the first. A plan almost as good is that of delaying culling until after the second litter and keeping the best $\frac{1}{5}$ to $\frac{1}{4}$ of the sows for a third litter at 2 years of age. Progress is retarded by retaining more than the optimum proportion of older sows, because the less intense culling of sows and the longer interval between generations is only partly offset by the more severe culling of gilts and the greater accuracy of sow culling.

Having sows farrow two litters per year is definitely advantageous. It permits the accuracy of selecting boars and gilts to be improved by basing the dam's productivity on two litters instead of one. It also means that the more productive sows may be kept for additional litters with a minimum increase in average interval between generations.

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NEWS AND NOTES

In the February, 1944 issue of the JOURNAL OF ANIMAL SCIENCE, page 101, under Chairmen of Committees for 1944, Committee on Investigations, should read P. B. Pearson (Texas) instead of W. E. Krauss (Ohio).

D. H. Udall, Professor of Veterinary Medicine, Cornell University, Ithaca, New York, has recently published the fourth revised edition of his book, "The Practice of Veterinary Medicine." This edition was published in 1943 by the autnor in Ithaca, New York.

R. T. Clark, of Montana State College, has recently returned from England where he was on a special livestock assignment for several months.

Thomas G. Paterson, Secretary of the Texas Hereford Association and at one time on the animal husbandry staff at the University of Minnesota, died at Callas, Texas, on February 19.

George R. Henderson, formerly a livestock specialist for the Colorado Agricultural College and more recently holding a major's commission in the Remount Service of the Army has been appointed extension animal husbandman in the Utah Extension Service succeeding H. H. Smith.

B. C. Johnson has been made assistant professor and assistant chief in animal nutrition at the University of Illinois.

Ralph E. Comstock has been appointed associate in animal industry in charge of breeding research at the North Carolina Experiment Station.

Hector G. McDonald, Assistant Professor in Animal Husbandry, Washington State College, has resigned to become manager of a ranch in Alberta, Canada, and was succeeded by Everett J. Warwick at Pullman.

R. M. Lancaster is now assistant extension animal husbandman at Mississippi State College.

W. Jefferson Harris, formerly a member of the animal husbandry staff, University of Kentucky, and more recently in private work, died suddenly in May, 1943.

K. L. Turk, head of the Department of Dairy Husbandry, University of Maryland, has resigned to accept the position left vacant at Cornell University by the death of E. S. Savage.

Jas. B. Outhouse of the animal husbandry staff, University of Maryland, has resigned to become an ensign in the U. S. Navy.

W. E. Pace, Jr., swine specialist in the Georgia extension service, has resigned to become superintendent of swine production at the State Prison Farm, Reidsville, Ga.

Marshall C. Heck, recently with the National Live Stock and Meat Board has accepted appointment as assistant extension animal husbandman in the Arkansas Extension Service.

D. W. Williams, Professor of Animal Husbandry at the Texas A. & M. College, has been granted leave to accept a major's commission in the Specialist Reserve Corps of the U. S. Army and reported at Fort Custer, Mich., on December 26.

J. D. Harper, for 20 years editor of the National Live Stock Producer, has resigned to become chief of the Midwest Bureau of Pathfinder Magazine at Chicago.

Alexander Johnston, of the animal husbandry staff of the University of Wyoming and formerly with the U. S. Bureau of Animal Industry, has been made chief of the wool division of the meats and livestock branch, Office of Distribution, WFA, succeeding James M. Coon.

W. A. Hagan, Dean of the College of Veterinary Medicine, Cornell University, has been granted a year's leave of absence to accept appointment as special assistant to the Chief, U. S. Bureau of Animal Industry.

W. L. Stangel, Head of the Department of Animal Husbandry, Texas Technological College at Lubbock, has been elected head of the Texas Agricultural Workers' Association for a two-year term.

Daniel T. Cox, a graduate of the University of Maryland in animal husbandry and formerly with The Eastern Breeder, has been employed by the American Shorthorn Breeders' Association as its eastern field representative.

P. T. Brown, Extension Animal Husbandman at Purdue University, was elected a director of the Shorthorn Club at the recent annual meeting in Chicago.

M. P. Jarnagin, Head of the Animal Husbandry Department, University of Georgia, and A. L. Harvey of the Animal Husbandry Department, University of Minnesota, made addresses before the recent annual meeting of the Horse and Mule Association of America at Chicago.

Paul E. Howe and Ralph W. Phillips, whose offices almost adjoined at the Beltsville Research Center, recently met unexpectedly in New Delhi, India. Colonel Howe, who is on the Surgeon-General's staff, U. S. Army, was on his way to China and Dr. Phillips was returning from that country where he has been on a special mission for the U. S. Government for the past year.

Fred R. Marshall, for 23 years secretary of the National Wool Growers' Association, has resigned and is now living in California.

J. C. Holbert of the animal husbandry staff, Iowa State College, is on a year's leave of absence while engaged in private livestock production.

W. H. Burkett, instructor and assistant in animal husbandry at the S. Dak. State College and Expt. Station, recently took military leave to join the armed forces.

Ralph McCall recently resigned his position on the animal husbandry staff, Montana State College, to accept a similar position with the University of Arizona.

John T. Rigden, extension animal husbandman, University of Arizona, has resigned his position to manage ranches owned by members of his family.

R. B. Hinman, for many years on the animal husbandry staff at Cornell University, died on July 25 after a long illness.

Forrest U. Fenn, of the Animal Husbandry staff at South Dakota State College, has joined the staff of *The American Hereford Journal*. Roy P. Wilkes, who has recently received his M.S. degree in Animal Nutrition at Colorado State College, will fill the position vacated by Mr. Fenn.

Ross H. Miller, formerly of the animal husbandry staffs of Oregon State College, Montana State College, and University of Nebraska, and more recently a field representative of the American Hereford Association, has joined the staff of *The American Hereford Journal*.

R. G. Johnson, head of the animal husbandry department, Oregon State College, who has been on a special assignment in China for the U. S. Government for the past year, has returned to his old post at Corvallis.

W. L. Blizzard, Dean and Director, Oklahoma A. & M. College, officiated as judge at the Shorthorn Congress recently held in Chicago.

E. A. Trowbridge, head of the Animal Husbandry department, University of Missouri, acted as judge at the National Hereford Show recently held at Dallas in connection with the Texas State Fair.

F. B. Morrison of Cornell University recently conducted a "Feeds and Feeding" short course for dairymen at the University of Georgia.